

Durham E-Theses

The implementation of a fabrication cell and the optimisation of a pull system with a decision support system

Panagiotakou, Ellie

How to cite:

Panagiotakou, Ellie (1994) *The implementation of a fabrication cell and the optimisation of a pull system with a decision support system*, Durham theses, Durham University. Available at Durham E-Theses Online: <http://etheses.dur.ac.uk/5554/>

Use policy

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a [link](#) is made to the metadata record in Durham E-Theses
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Please consult the [full Durham E-Theses policy](#) for further details.

Academic Support Office, Durham University, University Office, Old Elvet, Durham DH1 3HP
e-mail: e-theses.admin@dur.ac.uk Tel: +44 0191 334 6107
<http://etheses.dur.ac.uk>

The copyright of this thesis rests with the author.
No quotation from it should be published without
his prior written consent and information derived
from it should be acknowledged.

THE IMPLEMENTATION OF A FABRICATION CELL AND THE OPTIMISATION OF A PULL SYSTEM WITH A DECISION SUPPORT SYSTEM

by

ELLIE PANAGIOTAKOU

UNIVERSITY OF DURHAM

1991-1994

**This thesis is submitted to fulfil the requirements of a Masters of Science degree
at the University of Durham,
School of Engineering and Computer Science.**



- 2 JUN 1995

ACKNOWLEDGEMENTS

I would like to thank:

My parents for their financial and emotional support during the whole period of my studies, making it feasible for me to complete this research.

My supervisor, Dr Paul G. Maropoulos, for the valuable guidance during the progress of this research, for his help and support.

Reyrolle Switchgear Ltd., for providing the data to conduct the research, and the excellent co-operation of every employee of the company, I would like to refer especially to Mr Hugh Knox Production Manager, for his support assistance, and guidance in order to complete this research, additionally I would like to thank Mr Alan Lay Production Engineering Manager, and Ms Kate Strain Industrial Engineering Manager.

Dr Andrew Farrell, and Dr John T. Davies for their assistance in writing up this thesis, and their support for the duration of this research.

Prof. Peter B. Atwell for his invaluable help and guidance.

Finally I would like to thank Dr Costas Spanomanolis, who made it possible for me to start this research, for his support, assistance and guidance for the duration of the project.

ABSTRACT

Manufacturing Resource Planning (MRPII) systems are used by forty per cent of UK manufacturing companies (Little, 1990). In cases where the implementation of the system was successful, the companies have experienced reductions in inventories and lead times but the results were not always as good as they were anticipated. The justification of the major capital expenditure that is required for the implementation of the MRPII system was not always achieved by the benefits gained. Meanwhile, Just in Time (JIT) manufacturing environments experience benefits in terms of rapid stock-turns, due-date compliance and quality that MRPII users could not resist.

This research initially focused on the investigation of the reasons of failure of MRPII implementations in low volume high variety manufacturing environments. The main reason being that the implementation of the MRPII system was not complemented by a shop floor re-organisation.

The thesis reports an investigation and some elements of implementation of a change in the manufacturing operations of a company.

The manufacturing environment that was used for this investigation was Reyrolle Switchgear Ltd. The production control system used by the company is MRPII, however, the implementation of the system was not as successful as it was anticipated. In order to cope with excessive stock, management decided to introduce a pull system for controlling the production of a limited number of components. The application of the pull system was limited because of the complexity in controlling the response of the manufacturing facilities, which had a functional layout.

In order to establish an effective pull system, cellular manufacturing was introduced. The methodology used was "Line Analysis" which is a sub technique of "Production

Flow Analysis". The pull system was complemented by a Decision Support computer based system in order to facilitate and enhance planning and inventory control.

The changes were implemented and considerable improvements were achieved. The candidate is a researcher/investigator partly promoting the changes reported, implementing methods and investigating their effect.

CONTENTS

CHAPTER 1: PRODUCTION CONTROL SYSTEMS.....	1
1.1. INTRODUCTION	1
1.2. JUST-IN-TIME.....	2
1.3. MANUFACTURING RESOURCE PLANNING.....	5
1.4. OPTIMISED PRODUCTION TECHNOLOGY	9
1.5 DISCUSSION.....	11
1.5.1. JUST-IN-TIME.....	11
1.5.2 MANUFACTURING RESOURCE PLANNING.....	12
1.5.3. OPTIMISED PRODUCTION TECHNOLOGY	13
CHAPTER 2. PRODUCTION CONTROL AND FACTORY LAYOUT.....	15
2.1. THE MRPII CHANGE.....	16
2.2. CELLULAR MANUFACTURING AND GROUP TECHNOLOGY	17
2.3. PRODUCTION FLOW ANALYSIS	19
2.3.1. FACTORY FLOW ANALYSIS	19
2.3.2. LINE ANALYSIS.....	20
2.4. LINK BETWEEN LAYOUT AND PRODUCTION CONTROL.....	21

CHAPTER 3. UNDERSTANDING THE INDUSTRIAL ENVIRONMENT	23
3.1. THE PRODUCTS	23
3.2. MEDIUM VOLTAGE PRODUCTS	24
3.2.1. LMT SWITCHGEAR:	24
3.2.2. LSR SWITCHGEAR:.....	25
3.2.3. YMV SWITCHGEAR:.....	25
3.2.4. SMS SWITCHGEAR:	25
3.2.5. RO SWITCHGEAR:.....	26
3.2.6. ESR SWITCHGEAR:.....	27
3.3. HIGH VOLTAGE PRODUCTS	27
3.4. THE PRODUCTION CONTROL SYSTEM.....	27
3.5. ORDER INTAKE.....	28
3.6. DEMAND MANAGEMENT	28
3.7. MATERIAL REQUIREMENTS PLANNING	29
3.8. SHOP FLOOR	30
3.8.1. MACHINE SHOP	30
3.8.2. FABRICATION SHOP	30
3.8.3. ASSEMBLY SHOP	31

3.9. SHOP FLOOR ORGANISATION	32
3.10. SHOP FLOOR CONTROL	32
3.11. DISCUSSION.....	34
CHAPTER 4. A COMPONENT BASED CELL.....	36
4.1. THE SHEET METAL SHOP.....	36
4.2. DATA COLLECTION.....	37
4.2.1. EXISTING MATERIAL FLOW.....	37
4.2.2. SIMPLIFICATION OF THE MATERIAL FLOW.....	40
4.2.3. FROM-TO ANALYSIS	44
4.3. DYNAMIC PROGRAMMING.....	48
4.3.1. THE TRAVELLING SALESMAN PROBLEM	48
4.3.2. THE DEFINITION AND SOLUTION OF THE PROBLEM	49
4.4. PRIORITY AND MATERIAL FLOW RULES.....	51
4.5. FEEDBACK TO MRPII.....	53
4.6. DISCUSSION.....	54
CHAPTER 5. THE DECISION SUPPORT SYSTEM.....	56
5.1. EXPERT SYSTEMS.....	57
5.2. CRYSTAL 4.5.....	58

5.3. THE DECISION SUPPORT SYSTEM'S OBJECTIVES.....	59
5.4. THE DESCRIPTION OF THE SYSTEM	61
5.4.1. THE DATABASE	61
5.4.2. THE EXPERT SYSTEM	63
5.4.3. ADD/UPDATE ORDERS.....	63
5.4.4. JOBS TO BE STARTED.....	67
5.4.5. ORDERS RELEASE/RECEIPT FROM THE FABRICATION SHOP.....	68
5.4.6. UNEXPECTED INVENTORY REPLENISHMENT.....	68
5.4.7. CLOSE ORDERS.....	68
5.5. INTEGRATING THE SYSTEM.....	68
CHAPTER 6. DISCUSSION AND CONCLUSIONS.....	79
BIBLIOGRAPHY.....	82
APPENDICES	
APPENDIX I. DATA COLLECTION	
APPENDIX II. INSTALLATION OF THE SYSTEM	
APPENDIX III. THE SOURCE CODE FOR THE DECISION SUPPORT SYSTEM	

FIGURES

<i>FIGURE 4.1. FROM-TO ANALYSIS CHART</i>	39
<i>FIGURE 4.2 THE SCHEMATIC DIAGRAM OF THE MATERIAL FLOW AT THE LIGHT FABRICATION SHOP.....</i>	40
<i>FIGURE 4.3. FIRST PASS FOR THE IDENTIFICATION OF THE SIMPLIFIED ROUTINGS</i>	42
<i>FIGURE 4.4. SCHEMATIC DIAGRAM OF THE SIMPLIFIED ROUTINGS.....</i>	43
<i>FIGURE 4.5. THE GENERIC ROUTING IDENTIFIED FOR THE LIGHT FABRICATION SHOP</i>	43
<i>FIGURE 4.6. FROM TO MATRIX BEFORE THE LINE ANALYSIS.....</i>	47
<i>FIGURE 4.7. FROM TO MATRIX AFTER THE LINE ANALYSIS</i>	47
<i>FIGURE 5.1. THE PLANNING PROCEDURES OF THE DECISION SUPPORT SYSTEM.....</i>	60
<i>FIGURE 5.2. THE STRUCTURE OF THE DATABASE</i>	70
<i>FIGURE 5.3. THE ASSEMBLY ORDERS FILE</i>	61
<i>FIGURE 5.4. THE INVENTORY FILE.....</i>	62
<i>FIGURE 5.5. THE FABRICATION ORDERS FILE.....</i>	62
<i>FIGURE 5.6. THE MAIN MENU OF THE DECISION SUPPORT SYSTEM</i>	71
<i>FIGURE 5.7. THE STRUCTURE OF THE 'ADD/UPDATE' MODULE</i>	72
<i>FIGURE 5.8. THE INPUT SCREEN FOR THE ASSEMBLY ORDERS FILE</i>	73

<i>FIGURE 5.9.</i> THE MESSAGE THAT THE USER GETS WHEN THERE IS NOT ENOUGH TIME FOR PRODUCTION	73
<i>FIGURE 5.10.</i> CHANGES THAT CAN BE PERFORMED TO THE DATA HELD BY THE DATABASE	66
<i>FIGURE 5.11.</i> THE STRUCTURE OF THE 'JOBS TO BE STARTED' MODULE	74
<i>FIGURE 5.12.</i> THE OUTPUT SCREEN WHICH INCLUDES ALL THE ORDERS THAT SHOULD START ON A SPECIFIC DAY	74
<i>FIGURE 5.13.</i> THE OUTPUT SCREEN WHEN NO ORDERS WERE PLANNED TO START ON A SPECIFIC DAY	75
<i>FIGURE 5.14.</i> THE STRUCTURE OF THE 'FABRICATION ORDERS FILE' MODULE	76
<i>FIGURE 5.15.</i> THE OUTPUT SCREEN FOR THE NUMBER OF ORDERS THAT SHOULD BE RELEASED ON A SPECIFIC DAY	76
<i>FIGURE 5.16.</i> THE STRUCTURE OF THE 'UNEXPECTED INVENTORY REPLENISHMENT' MODULE	77
<i>FIGURE 5.17.</i> THE INPUT SCREEN FOR THE INVENTORY RECEIVED UNEXPECTEDLY	77
<i>FIGURE 5.18.</i> THE STRUCTURE OF THE 'CLOSE ORDERS' MODULE	78
<i>FIGURE 5.19.</i> THE INPUT SCREEN TO UPDATE THE SYSTEM ABOUT WHICH ORDERS ARE COMPLETED	78

To my father
and
the beloved memory of my mother

CHAPTER 1. PRODUCTION CONTROL SYSTEMS

1.1. INTRODUCTION

A manufacturing system is a configuration of resources combined for the provision of goods. The resources are machines, materials used and labour. The objective of any manufacturing system is to "make money". Therefore, the resources have to be co-ordinated so that the operating cost is minimised, while delivering the products on time and at the quality requested.

Operations management is concerned with the design and operation of a manufacturing system. Various methods have been developed for inventory control, scheduling, production planning, capacity planning and machines layout arrangement. These aspects of management are crucial to the effective and efficient operation of a manufacturing system. All the aforementioned activities have to co-exist in a given manufacturing system and also co-ordinated in order to meet the objectives of the business. The co-ordination is achieved by the production control system used by the company. The production control system translates the business objectives into day-to-day targets and activities.

In this first chapter, three contemporary production control systems will be discussed Just-in-time, Manufacturing Resource Planning and Optimised Production Technology.



1.2. JUST-IN-TIME

The Just-in-Time (JIT) production control system is presented first, because it is the control system that has set the targets in many manufacturing environments.

The philosophy that supports a JIT production control system acknowledges the desire to eliminate all forms of waste in a manufacturing environment. Waste, is anything that adds cost but no value to the product. Non value adding (NVA) parameters are stock, work-in-progress (WIP), queues, transportation, set-up times, scrap, rework, machine breakdown, inspection and material handling (Cheng, 1991; Japanese Management Association (JMA), 1985; Hall, 1981, 1983, 1987; Shingo, 1985, 1986, 1989).

The JIT philosophy and production control system evolved after forty years of continuous improvement by Toyota. The management of the company realised at the end of the 40's, that in order to survive, they had to catch up with American automotive companies. Through the years the employees and management worked together to achieve what now is considered to be the best practice in manufacturing (Hall, 1981, 1983, 1987).

The objective in a JIT environment is to deliver the product(s) on time, at the exact quantity and quality required. It aims to stockless production, everything produced to an order.

Timing and accuracy in a JIT environment are of crucial importance. Deficiency can only result in inventory increase, therefore quality is the cornerstone for a JIT environment. The three enemies of total quality complexity, variation and attitude, are tackled at every stage of the manufacturing system .

At source: raw material and components, through integrated customer-supplier relationships, mistake-proofing Poka-Yoke systems of inspection (Shingo, 1985, 1986, 1989), and preventive machine maintenance. At design:

design the product to be right first time. In process: through process control, Statistical Process Control (SPC) which measures the variation within a process (Feigenbourn, 1986). In people: distributed responsibility on the shop-floor for quality, and enhanced teamwork (Jewitt, 1990).

Total quality management is implemented throughout all the activities within a company.

Generally, JIT is characterised by simple and visible systems. Control is conducted through posted schedules, charts, boards and signal lights which display all the information required. The visibility and simplicity enhances the accuracy of the data concerning production.

In order to achieve zero inventories the batch sizes are kept to a minimum. This contributes to the reduction of lead times, as a direct reduction of the machine, and queuing time required. However issues emerge, which are related to set up time requirements and quality. A number of optimisation techniques have been developed so that the benefits from the reduced batch size can be realised (Hall, 1981, 1983, 1987; Shingo, 1985, 1986, 1989).

The organisation of the shop floor is vital to effective control and the establishment of simplicity and visibility. In a JIT environment the arrangement of machines is based on the product requirements rather than the functionality of the machines. Groups of machines are brought together to manufacture a product or a range of similar components. The arrangement of machines is U-shaped, C-shaped or there is a linear arrangement in order to minimise the travelling distance and allow close contact between the operators. Next to the machines there are clearly identified input, and output areas. The input area is for the components to be processed, whereas the output area is for those components that have already been processed by the machine. This organisation of the shop floor enhances visibility with respect to material flow and problems that might occur can be identified easily. Additional measures concerning the material flow are taken in order to prevent the increase in

WIP and queues at the shop floor. Smooth flow of material is achieved by levelling and freezing the master schedule and balancing the detailed schedules. Levelled schedules are constructed at the master production planning level, the requirements in terms of capacity are spread in order to achieve an equal distribution of the load. On the shop floor level, balance has been achieved between operations so that the production rate meets the sales rate.

Due to the fact that lateness and smooth material flow are mutually exclusive, emphasis is placed on parts delivery timing. The activities in a JIT environment can be characterised as a chain of supplier-customer network. The production in a JIT environment is driven by the customer's demand at every stage. A customer is the next station which will receive the components, the sub-assemblies, or the end product. The pull system that has been developed ensures that the machines and operators will work only on what is required. Kanban is this pull system, and it is used to initiate production at work centres (JMA, 1985; Hall, 1981, 1983, 1987; Shingo, 1985, 1986, 1989, 1990; Voss, 1989).

Kanban as a system is developed to serve inventory control, quality control, handling methods and material flow purposes. Inventory control is achieved by working only when the parts are required by the subsequent work centre. Every shop floor order is accompanied by a part-dedicated container which will be replenished with the finished components, solving the material handling problem. In some cases, the containers are constructed in such a way that defective products will not fit in, achieving simple and visible quality control. There are two variations of a Kanban system (JMA, 1985; Hall, 1981, 1983, 1987; Shingo, 1985, 1986, 1989):

1. **Single card Kanban.** In a single Kanban parts are produced and bought according to a daily schedule and deliveries to the user are controlled with a Container-Kanban (C-Kanban). In effect, a single card system is a push system of production, coupled with a pull system for deliveries.

2. Dual card Kanban. The two card system is a more complex way of controlling activities. This system includes a move (as in single card) and a production card. The production card authorise the production of more components. There is a marked area -Kanban square- for placing the full containers. When the square is full, no production should take place.

JIT is a philosophy that initiates change towards improvement. It is a continuous improvement program. Improvement, however, is not something that can be imposed from the top management. What is required is commitment and total involvement from management, employees and suppliers. Training and education for a JIT environment are of crucial importance, so that employees will contribute to the overall objectives. In order to motivate their employees a number of schemes have been developed, which enhance the participation of the workforce. The Japanese have introduced Kaizen. The actual meaning of the word Kaizen is improvement, slow steady ongoing changes throughout the plant resulting in continuous improvement. A group of people forms a team to make proposals for improvement concerning their working environment. The team is empowered with people from other parts of the company such as designing, engineering and suppliers, in order to accumulate all the knowledge required, and enhance teamwork and communication throughout the company (Cheng, 1991; Guthrie, 1987; Galbraith, 1991; Voss, 1989).

One of the key success factors of JIT is defect-free purchased parts. High quality goods must be delivered frequently and on time. From the process point of view, a supplier is a remote work centre and all the rules for waste elimination, and quality should apply. JIT companies involve their suppliers at the design stages so that they understand the requirements and allow them to make suggestions to improve the quality of the product (Cheng, 1991; Golhar and Stamm, 1991; Hodgson, 1987; Hutchins, 1990; Nellemann *et al.*, 1982; Guthrie, 1987; Galbraith, 1991).

1.3. MANUFACTURING RESOURCE PLANNING

Manufacturing Resource Planning (MRPII) is a top-bottom approach to production management and control. It is a Computer Aided Production Management (CAPM) system consisting of a number of software modules which translate the customer and forecast demand into day-to-day activities. It is supported by a number of databases which contain all the information required to plan and schedule production.

MRPII evolved from Material Requirements Planning (MRP). MRP origins go back to the 1950's and it is a production planning system that is based on the inventory of the available components in the factory. In the 1960's Oliver Wight developed these methods for production planning into a closed loop MRP system based on computerised databases.

MRPII is mostly implemented by American and European companies. The reason being that they focus on more customised products, bigger variety and lower volumes. The complexity in terms of data handling is increased and software systems tend to be the right solution to manage this kind of production.

Master Production Scheduling (MPS) is the first software module in the hierarchy of the MRPII system. MPS displays the plans at the highest level, in terms of end product units based on the marketing forecast and the customers' demand. The use of MPS facilitates the distribution of the product requirements over a time period in order to achieve smooth workload. What-if scenarios can be tried out to realise the effect on the shop floor, based on the rough cut capacity requirements for each product. The best what-if scenario will give a comprehensive view of the future requirements in terms of number of people, shifts, and subcontracting to meet the demand. Based on the above information the capacity of the factory has to be adjusted accordingly.

The master production schedules have to be broken down into finite detail, so that all the material requirements can be determined. This is the basic outline for the Material Requirements Planning (MRP) module of MRPII.

The bill of materials (BOM) for each of the end products in MPS is exploded in order to determine the gross requirements of all the components that constitute the end product. The MRP database contains the lead times for all the parts in the BOM database. Based on the due date of the product it back schedules all the requirements taking into account the structure of the product. When the time phased requirements are determined for the demand defined at the MPS, the planning horizon will be divided into "time buckets" and the requirements for components will be aggregated. These time buckets usually depend on the value of the parts, which is determined using the 'ABC' classification. For example batches for 'A' parts are more frequent than batches for 'B' or 'C' parts. There is a number of different rules that can be applied for batching requirements such as minimum or maximum quantities, multiple batches, lot-for-lot.

The next step for MRP is to estimate the net requirements for the time buckets. The inventory (stock and WIP) for each of the periods is subtracted from the gross requirements. What is left will constitute the work orders, which subsequently will be released to the shop floor.

The MRP run usually takes place once a week, or during holiday periods. Depending on the amount of data that have to be processed it can either run on a regeneration mode, erase all the planning data and generate them again, or on the net change mode, in which it changes only what has been altered.

Shop Floor Control (SFC) software module will explode each work order into a detail sequence of operations and back schedule them based on the due dates assigned by MRP. The information concerning the routings and times against each of the operations will be retrieved from the production routings database. There are two techniques that can be used for scheduling at the SFC level:

1. **Priority sequencing:** the earlier the due date, the higher the priority for the order. A dispatch list is generated daily by the system for

every work centre which shows the orders that have to be completed and what their priority is. Whenever the due date of an order changes, the system makes the appropriate adjustments to the dispatch list.

2. Finite loading: According to the finite loading technique, every work station is loaded up to its capacity. This technique simulates the actual job starting and stopping in order to produce a detailed schedule. It takes into account the capacity of each work centre and loads the machines according to the results of the simulation and without ever exceeding the work centre's capacity. The capacity of a machine is considered to be constant, and the technique cannot adjust the capacity levels according to the workload.

When the scheduling procedure is complete, due dates are assigned to each operation for the production of components. As soon as an operation is finished, the information is fed back to the system, in order to maintain visibility in terms of the progress of an order and updates automatically the inventory database. Additionally the accounting records for production are updated when the feedback action takes place. Stock, WIP, and operating costs are automatically estimated.

Capacity Requirements Planning (CRP) utilises the information produced by the MRP and SFC explosion process which include actual lot sizes and processing times for both open shop orders, and orders that are planned for future release. It also takes into account the demand for service parts, and other demands that may not be accounted for, and any additional capacity that might be required by MRP planners reacting to scrap items, record errors, and so on. Based on this information, the detailed labour and machine capacity is determined (Love *et al.* 1989; Swale, 1990).

MRPII is classified as a 'push' system. Any future demand, either forecast or actual demand, is translated into detailed plans that are pushed through the factory to meet the due dates generated by MPS. The modules mentioned above MPS, MRP, CRP, and SFC are the generic parts of MRPII. The requirements of the manufacturing environment, however, determine whether all of the above modules will be used or

not. Additionally, other modules are available, for example accounting and time management which can be used with MRPII that contribute to the generation of a Computer Integrated Manufacturing environment (Vollman *et al.*, 1988; Riggs 1988; Hall, 1981; Lockyer *et al.*, 1988; Lawrence, 1987; Primose, 1990; Archer, 1991; Foddy, 1990;).

1.4. OPTIMISED PRODUCTION TECHNOLOGY

Optimised Production Technology (OPT) was first developed in Israel in the 70's, by a research group consisting of four people led by Dr. Eliyahu Goldratt. They acknowledged that the objective of every manufacturing company is to make money, both at present and in the future. They defined that at the shop floor level the profitability depends on:

1. Throughput: the rate at which money is generated through selling finished goods.

2. Inventory: the money that the system has invested in purchasing things which intends to sell.

3. Operating expense: all the money that the system spends to turn inventory into throughput.

Based on these three measures a new measure for productivity was given:

"Increase of throughput while decreasing inventory and operating expense."

OPT philosophy brought a revolution to the conventional way of thinking in terms of manufacturing. A set of ten rules should be adopted by a company in order to implement OPT. These rules being:

1. Balance flow, not capacity.

2. The level of utilisation of a non-bottleneck is not determined by its own

- potential but, by some other constraint in the system.*
- 3. Utilisation and activation of a resource are not synonymous.*
 - 4. An hour lost at a bottleneck is an hour lost at the system.*
 - 5. An hour saved on a non-bottleneck is an illusion.*
 - 6. Bottlenecks govern both throughput and inventory.*
 - 7. The transfer batch may not, and many times should not equal the process batch.*
 - 8. The process batch should be variable not fixed.*
 - 9. Schedules should be created by looking at all the constraints in parallel.*
 - 10. Lead times are the result of a schedule and cannot be pre-determined.*

The philosophy identifies two phenomena in a manufacturing environment whose role is crucial: dependent events, and statistical fluctuation. Processes rely upon the completion of the preceding operations, and process times fluctuate around an average. The two phenomena dictate that the capacity in a plant must not be balanced and bottlenecks exist. In simple terms, OPT considers bottlenecks (capacity constrained resources) as the "drummer" that gives the pace to the production. The bottlenecks should never starve, providing that they produce for selling purposes and not for stock. A buffer should exist before the bottleneck, in order to keep it working until new orders reach the machine. The production of the parts is initiated depending on the situation at the bottleneck machine.

This is the basic outline for the OPT software system itself. The schedules established by the OPT system are based on a combination of finite and infinite capacity scheduling. The information relating to each finished product (process routes, process times, set-up times, and so on) is stored in a network form. An elaborate set of checks and cross checks taking into account the work centre details, validates this as far as possible. The system back-schedules the orders which were derived from the marketing forecast based on infinite capacity. This schedule is used to classify resources as critical and non critical, based on utilisation. The critical resources are the bottlenecks. The package then uses a proprietary algorithm to optimally forward

schedule the orders through the bottleneck resources. Finally, the orders are scheduled through the non critical resources in such a way that the optimal schedule on the critical resources is not disturbed and a buffer of safety capacity is included to allow for disruptions. The heart of this approach is the algorithm which carries out the optimal scheduling of the critical resources. The algorithm has management parameters which enable the system to be fine tuned to specific company objectives (Vollmann, 1988; Lawrence, 1987; Aggarwal, 1985; Johnson, 1990; DTI, 1989; Goldratt, 1993).

1.5. DISCUSSION

1.5.1. JUST-IN-TIME

JIT, is a risky manufacturing philosophy because inventories are kept to a minimum and planning is short term. Therefore there must be a number of improvements to be realised simultaneously, for the system to operate smoothly. Low inventories make the system inflexible when something goes wrong, or changed. JIT depends on pro-active measures in terms of quality, maintenance and deliveries, because machine breakdown, production of defective components or late deliveries from the suppliers can result in major disruption as there is nothing to anticipate for the loss.

Although, JIT philosophy is easy to comprehend, manufacturers experience extreme difficulties in implementing the system. It is the cultural issues of JIT that make it a hard and a very lengthy process to be realised. These issues, are extended over the company's borders to the suppliers. In order to achieve the suppliers' motivation long term contracts have to be agreed, so that they realise the benefit.

There is a false perception that control in JIT environments is conducted manually. In reality, the use of computers is crucial. A JIT environment requires

a planning system to smooth production and calculate optimal manufacturing in terms of costs, lead times, and resources. There is a need for co-ordinating the deliveries from the suppliers, and communicating with them to specify what is required, which is achieved with computer networks. Preventive maintenance is achieved by using computer based systems to monitor, machines, and tools performance, and make the appropriate adjustments to the production whenever it is required.

In order for JIT to work ideally a deterministic environment is required. Deterministic being an environment or a system that is completely predictable. The predictability is associated with the demand profile. Completely predictable demand is actual demand and not forecast. Pull systems do not recognise future events. The inventory level triggers the production. Pull systems are difficult to operate in environments where demand varies not only in terms of numbers but also in products because the deterministic nature is abolished.

1.5.2. MANUFACTURING RESOURCE PLANNING

MRPII is best suited to companies which make discrete multi-component items repetitively, or as one-off.

An MRPII environment is usually highly computerised. Although the data is readily available, the output of the system can be as good as the input. The output from MRPII modules is highly dependent on accurate data that should be fed into the system systematically. The updating procedures are very demanding in terms of time, as the data should be reviewed quite often. This is the result of the dynamic nature of a manufacturing environment which is imposed by the need to meet the customers requirements in terms of quality and due date compliance.

Although parameters like lead times, routing and capacity are considered to be constant by MRPII in reality they change constantly. That change has to be reflected back to the system in order to maintain accurate plans.

The added complexity, due to the large number of parts that MRPII databases account for, makes it difficult for the planners to understand the full ramifications of their actions. The system database becomes progressively more extensive to cover all products, material processes and resources. Data validity is difficult to be achieved, mainly because of the database size. The operational response deteriorates as size grows. Capacity planning at the MPS level becomes more complex and unpredictable. At a detailed level (CRP) the calculations take longer and when problems emerge the re-run of the MPS-MRP-CRP is considered to be very time consuming. What usually happens under these circumstances is that CRP is not used at all and when it is realised that the manufacturing facility cannot cope, either MPS rescheduling takes place, or fire fighting and expediting. This results in priority changes which creates confusion at the shop-floor.

Unlike JIT, MRPII lacks any strategy for quality control, production smoothing, line balancing, preventive maintenance, good liaison with suppliers, and other improvements in the production process. MRPII can provide accurate records of what is going on at the factory, facilitating effective control. As control becomes more effective the benefits which can be realised are reduction in inventory and lead times. Radical change and improvements, however, can not be achieved only by using MRPII.

1.5.3. OPTIMISED PRODUCTION TECHNOLOGY

OPT is half way between JIT and MRPII, offering strengths of both JIT and MRPII but combining weaknesses too.

OPT is similar to MRPII in many respects. Both systems require large, and complex databases which hold information about products and machines. The issue of data accuracy also applies to OPT.

The computational power, however, required for OPT is greater due to the 'what-if' scenarios that it carries out, and the bottleneck scheduling techniques. As OPT actually schedules the day to day operations, the shop floor data accuracy is a much more critical issue than for MRPII. For an OPT system to operate it is imperative that accurate production data is available, otherwise the manufacturing system can not be modelled.

OPT bears resemblance to JIT, in terms of cost accounting, variable lot sizing and inventory reduction. The cultural change that is required constitutes a serious problem for the implementation of the system. In terms of cost accounting, it challenges the traditional ways of estimating cost and productivity, moving from the evaluation of single departments to the factory as a whole entity. It redefines utilisation, allowing idle time for the workforce when they meet their targets.

In real life situations, a manufacturing system might not use exclusively one of the above mentioned control systems, but aspects from all of them combined to give the best results depending on the requirements. Hybrid systems have evolved, mostly due to the customised requirements of each manufacturing environment.

In the second chapter of this thesis focus is placed on manufacturing environments that use Manufacturing Resource Planning. The traditional ways of shop floor organisation are discussed for the specific environments together with the impact these traditional ways have on the production control system. Alternative ways of shop floor organisation are also investigated.

CHAPTER 2. PRODUCTION CONTROL AND FACTORY LAYOUT

The ways of controlling a complex manufacturing environments used to have two attributes that totally contradict JIT philosophy; fragmentation and functional organisation. Machines and people were organised in groups that performed similar functions. Communication between groups was carried out only when it was necessary. These groups used to constitute islands of expertise since all the skills related to a specific function existed in the same area, and communication was rarely required with other departments. Although, teamwork, flexibility, and visibility within the same group were enhanced, that did not apply across the business (Burbidge, 1989; 1991).

Decision making in the traditionally organised manufacturing environments was a function conducted by the upper levels of hierarchy, and the directives were passed downwards in order to be implemented. One of the common characteristics of these environments was that the hierarchical structure consisted of many levels. This organisation structure made it difficult for feedback to reach the decision making levels (Smith, *et al.*, 1989).

On the shop floor there was a complete lack of decision making and involvement. Each functional group had to meet its own targets, which were usually related to money. These measures of performance aimed to increase the utilisation of machines rather than the due date compliance, with the belief that the demand requirements would be met. That resulted in excess inventory and backlog since the main issue was to produce as many parts as possible, with disregard to the capacity constraints and what was actually required.

2.1. THE MRPII CHANGE

The implementation of the MRPII system facilitated communication between the departments in the manufacturing environment. Control was enhanced, as visibility increased due to the information generated and provided by the system. On the shop floor, however, not many things changed. This was due to: a) MRPII had an effect on the middle hierarchy levels connecting the top management to the shop floor, b) shop floor organisation is not an issue dealt by MRPII, c) the top bottom approach was enhanced even more. In simple terms the shop floor practices did not change.

It should be realised that the implementation of an MRPII system will not enforce change. The MRPII is simply a decision support system to facilitate production management. The basic functions of the system are material planning and the provision of information concerning the future situation on the shop floor, based on the data it generates. The information should be used to identify potential problems and actions should be taken to prevent them (Galvin, 1986).

The CRP module acts as the feedback from the shop floor to the planning levels. Although it is not a dynamic system the capacity of the shop floor can be assessed and realistic plans can be produced. In real world however, CRP is hardly used because of the extreme computational effort that is required.

Shop floor control is a very critical issue for managing a manufacturing environment. It is not always possible to anticipate all the deviation to the original plan that might occur. The top-bottom approach to shop floor control has to be supplemented in order to ensure that the original plans will be met and that critical problems will be tackled at the source of the problem, which is shop floor (Burbidge, 1978, 1989, 1991; Love, 1986, 1989, 1992).

In order to enhance control on the shop floor visibility has to be established. The visibility should drive the shop floor towards the business objectives, which are due

date compliance, and minimum cost in terms of inventory and operations. The functional organisation of the shop floor should be altered, and focus should be placed on shop floor organisation around the product needs (Savage, 1985).

Cellular manufacturing, and Group Technology are techniques use to arrange the machines layout taking into account the product requirements.

2.2. CELLULAR MANUFACTURING AND GROUP TECHNOLOGY

A cell is formed by collecting together all resources that are needed to completely manufacture a range of products. These resources are; machines, people, tools, jigs, fixtures, and drawings. The product at a cell level is a range of components or assemblies. The cell operates as a supplier to other areas (cells) of the factory by providing the complete components. It may also function as a customer, by asking other cells to provide the goods or services that it requires to meet its demand (Burbidge, 1989, 1991; Love, 1986, 1989, 1992).

The criteria for the selection of the parts can be geometrical similarities, similar processes or routes, volumes, lead times, or customers. The similarities of the products result in a reduction in variety which makes control more feasible, and the day to day activities more manageable. The machines within the cell should be arranged in such a way that one-way material flow is achieved, thus reducing moving times and enhancing visibility on material flow. In cases where the existing routing of a part disturbs the one-way flow, alternative ways of manufacture should be considered. Although in theory, a cell should have the capability to convert raw material into end products, in practice it is usually difficult to achieve it. The reasons are related to the capital expenditure that is usually required to create a completely autonomous cell. Other cells, however, may have the capability, so subcontract procedures should be established between the cells in order for the components to be processed, but this should be kept to minimum levels. The owner cell should have the

capability of performing the major part of the operations (Burbidge, 1989, 1991; Love, 1986; Wells, 1989; Prickett, *et al.*, 1991).

Visibility should be incorporated in all the procedures within the cell. It is imperative that the cell should work on a firm schedule for a period of time. A firm schedule increases visibility in terms of the priority rules for the parts to be produced and targets achievements. Strict rules should be followed for the component movements in order to enable the workforce to identify the problems that might occur during production. The cell should be designed in such a way that it has ownership over schedules, and parts, and it is accountable for the quality and due date compliance. Responsibility should be assigned to the people within the cell concerning the day to day activities (Wells, 1989; Love, 1989, 1986; Burbidge, 1978, 1989, 1991).

Summarising the benefits of cellular manufacturing (Schonberger, 1984):

- 1) Reduced, more manageable span of control.
- 2) Smaller scale operation in terms of number of work centres, operators, parts, batches.
- 3) More predictable environment.

The product focus organisation is in reality a "Divide-and-Rule" method for reducing complexity. It is imperative, however, that a bottom up approach to control should be established in order to achieve self-regulation of the manufacturing system. Good communication relies on feedback procedures and feedback should originate from the shop-floor to adjust the plans produced by the MRP II system.

2.3. PRODUCTION FLOW ANALYSIS

Production flow analysis (PFA) is a technique used to plan the change in a factory from process organisation to product organisation and also plan the change from process layout to product layout. PFA can also be defined as a technique to simplify material flow in factories (Burbidge, 1989).

PFA is a progressive technique consisting of a succession of sub techniques. Company flow analysis is a sub technique which is used to simplify the flow between factories or divisions in large companies. When the best division of each factory, based on product organisation, is established Factory Flow analysis is used to simplify the material flow. Group analysis is used subsequently to group departments of the factory. The material flow between work centres is studied by Line Analysis. Finally tooling analysis is used to plan operation sequencing and to find sets of parts suitable for automation.

2.3.1. FACTORY FLOW ANALYSIS

Factory Flow Analysis (FFA), is used to plan the change in factories from component processing departments which are based on process organisation, to departments which complete particular sets or families of parts.

The methodology that is used to establish the optimum material flow is broken down into four distinct steps.

Step 1. Study the existing material flow. This stage constitutes the data collection phase of the analysis. The production routings of all the components are obtained or established (if not available). These routings are used to create the material flow system, which is a flow chart displaying all the stages for the manufacture of all the components including material stores and assembly stages. Subsequently a From-To analysis is performed that displays the transfers between the workstations.

Step 2. Simplification of the existing system. This stage involves the combination of associated operations into departments (cells), which complete most of the parts they make.

According to Burbidge (1989), the law of Pareto applies and a small percentage of the total number of production routings always accounts for a much larger percentage of the total number of parts. A primary network is then formed which consists of the generic flow paths for components. Subsequently, the generic routes can be combined when similar processes are shared, so that the flow is simplified even more. The last action is to estimate how many parts fit in the redesigned system.

Step 3. Eliminate exceptions. At this stage the parts that do not fit in the new design are taken into consideration. The objective is that the simplified system accommodates the majority of parts (90% and above) by re deployment of plant or new equipment.

2.3.2. LINE ANALYSIS

Line analysis (LA) is a sub technique of PFA which is used to analyse the flow of materials between machines and other workcentres within cells. The objective of this technique is to plan the best layout for the cell. It is similar to FFA as it uses network diagrams to analyse material flow

The first step for the analysis is the study of the existing flow system. The operation sequence data should be collected for the parts that use the specific cell. Subsequently the frequency chart, From-to analysis and the network flow diagram should be developed. The next step for LA is to plan the space requirements for the group of machines. The elements that should be considered are:

- 1) Temporary storage of materials and finished parts, the area that will be required depends on the size of the batches, the container sizes, the size of the parts produced and on whether racks are used for storage.

- 2) Lines of machines used in sequence, identify the machines that are used in groups and bring them together in order to eliminate the transfer time.
- 3) Machines loading and unloading since in machines with automatic processing the operator is free to operate other facilities.

2.4. LINK BETWEEN LAYOUT AND PRODUCTION CONTROL

The implementation of MRPII systems in complex environments is recommended due to the fact that as a planning and communication tools they can be very effective. Shop floor organisation is an issue that has to be addressed in order to take full advantage of the benefits that the system can provide. Excellence will only be achieved by establishing visible and simple systems throughout the company. The way forward should be the implementation of Cellular manufacturing techniques, wherever possible, and the involvement of the people who operate the system. Cellular techniques increase visibility and simplicity at the shop floor level, thus facilitating the improvement of the manufacturing system. In jobbing shop manufacturing environments there is an additional issue related to the complexity of the MRPII data. The cellular organisation can contribute to the simplification of the MRPII system since part of the planning and control activities can be distributed at the shop floor.

A real MRPII jobbing shop environment will be presented in the following chapter. Initially the traditional practice will be presented, and the problems that arouse from the existing policy. Focus will be placed, subsequently, on the re-organisation of the manufacturing facility. The Line analysis methodology for the formation of cells will be presented along with the benefits gained. The shop floor re-design involved the fabrication shop of the company. This constitutes a part of the manufacturing facility at Reyrolle Switchgear Ltd. A cell was created to produce components that have similar operation requirements.

Finally, the use of pull systems by the company will be evaluated, and a decision support system for effective inventory control, based on Kanban principles, that was developed, will be presented.

CHAPTER 3. UNDERSTANDING THE INDUSTRIAL ENVIRONMENT

Reyrolle was founded in 1901, and in 1904 the company was joined by Henry Clothier who was a switchgear designer. Until 1939 the company continued to grow and expand on the production site. During the Second World War the company produced anti-aircraft guns but when the war was over it continued the manufacture of switchgears. In 1968 it merged with Parsons and in 1969 Reyrolle/Parsons merged with Bruce Peebles Industries.

The flourishing British market of the 1960's ended and the next decade began with many redundancies. From 10,000 people the workforce was reduced to 1,500 in 1980. During this time attempts were made to improve efficiency and a program of reorganisation was implemented. From a large company it moved into a number of autonomous business units. The program was completed by the end of 1970's. In 1977 the group Northern Engineering Industries (NEI) was formed. It was a combination of the Reyrolle Parsons Group and the Clark Chapman Group. In 1990 Rolls Royce bought NEI.

3.1. THE PRODUCTS

The company, Reyrolle Switchgear Ltd., manufactures switchgear and circuit breakers for electric power stations. The switching capacity of the switchgear ranges from 3kV to 500kV. The substance used as an insulator is oil, vacuum, or SF₆ gas. Most of the components for the end-product are manufactured within the company. Raw materials, fuses, switches, relays, and bushings are purchased. The materials that are used are; steel, aluminium, brass, and copper. Steel is the main material for the fabrication of the cubicle, the shell of the switchgear. The thickness of the steel varies from 2-30 mm depending on strength requirements.

There are twelve different ranges of products that Reyrolle Switchgear manufactures. The switchgear differs in switching capacity, size, and method of operation. There is a logical split in medium voltage and high voltage products not only in terms of switching capacity but also due to size and demand profile.

3.2. MEDIUM VOLTAGE PRODUCTS

The main characteristics of the medium voltage production are

- a) High volume (approximately 700 panel per year).
- b) Low unit price (£15k on average).
- c) All of them are sheet steel cubicles with components mounted inside and outside.

The customer specification has a major effect on purchased parts and assembly operations (mostly wiring arrangements). The variability in terms of purchased components and wiring represents 30% of the value of the gear, whereas the remaining 60% is either common or with a very limited variation.

There are six different ranges for medium voltage product (*Appendix I*).

3.2.1. LMT SWITCHGEAR:

The LMT switchbreaker is a 13.8kV indoor oil break switchpanel. The gear has compact dimensions leading to reduction in building costs.

The LMT switch panel consists of welded steel enclosure divided into four compartments housing the circuit breaker, current transformers, busbars and auxiliary equipment. There are three different ratings available for 630A, 1250A and 2000A.

The oil circuit breaker is mounted on a steel wheeled carriage to allow horizontal movement between the service. The circuit breakers are of single break design, and

the operating mechanisms are either hand charged spring, motor charged spring, or solenoid operated.

3.2.2. LSR SWITCHGEAR:

The LSR switchgear is a 15kV indoor Sulphur Hexafluoride (SF₆) circuit breaker designed to fit a standard LMT enclosure. The breaker has all three interrupters in a common cast resin tank and it is operated by a spring mechanism. There are two circuits available, one for 630A and the other for 1250A. A third one is under development for 2000A.

3.2.3. YMV SWITCHGEAR:

The YMV switchgear is a 15kV indoor switchpanel, featuring vacuum interruption and utilisation of double tier concept of switchboard.

A double tier enclosure is provided for 630A and 1250A circuit breakers. The 630A circuit are located in the upper tier and the lower tier contains either 630A or 1250A circuits. A single tier enclosure is provided for 2000A circuits. Auxiliary equipment is mounted at the front of the enclosure.

The circuit breaker assembly is mounted on a swing frame which is locked into position in the enclosure during normal service. The isolation of the circuit breaker is achieved by 2-position sliding selectors mounted on either side of the vacuum interrupter. The selectors are operated simultaneously by a manually driven mechanism.

3.2.4. SMS SWITCHGEAR:

The SMS switchgear is a 36kV indoor switchpanel incorporating a circuit breaker using SF₆ gas for interruption. There are two breakers available which differ in normal current rating, one for 1250 A, and the other for 2000A.

The enclosure for SMS consists of steel assembly containing separate compartments for busbars, circuit breaker, primary circuit connections and auxiliary equipment.

The circuit breaker consists of three single phase SF₆ interrupter units and an operating mechanisms mounted on a wheeled carriage. The carriage allows the circuit breaker to move horizontally in and out of the enclosure. The three single phase units are operated by a common spring closing mechanism which can either be motor charged or manually charged.

3.2.5. RO SWITCHGEAR:

The RO is an outdoor oil-break switchgear suitable for urban distribution up to 15kV, at 630A. It consists of two ring main switches, and one tee-off fuse switch.

The welded steel oil filled tank is fitted with four hinged access covers. The directly connected version is fitted with two cable boxes mounted below the associated ring main switches. Extensible versions are fitted with busbars connections on either side to allow direct coupling with adjacent RO gears.

3.2.6. ESR SWITCHGEAR:

The ESR autorecloser comprises three rotary arc type interrupters enclosed in SF₆ gas. The gear consists of three main assemblies; a) a tank top plate on which are mounted the fare bushings, insulators, interrupters and operating mechanism, b) a tank which encloses the interrupters and mechanism, c) an electronic relay enclosed in a waterproof enclosure, which can be mounted adjacent to the tank, or mounted separately and connected by cable. The autorecloser is closed by a single stroke solenoid operated at phase voltage.

3.3. HIGH VOLTAGE PRODUCTS

High voltage products are structured in a different way to the medium voltage ones. Modular builds, are constructed for high voltage products whereas in medium voltage there is a standard panel. The components for the HV products are usually large components standardised but assembled in many different ways. The switching capacity of these gears is up to 550 kV normal current 4000A, and short circuit current up to 63kA. The method of insulation is SF₆.

The demand profile for HV products is different to MV. They are considered to be low volume but high unit value (£700k per unit). The HV switchgears have a periodical demand with a period of 2.5 years, when big contracts are undertaken.

3.4. THE PRODUCTION CONTROL SYSTEM

The production at Reyrolle Switchgear Ltd. is driven by a CINCOM MRPII production control system since 1989. The modules that were implemented were MPS, MRP, SFC, SFC Data Collection, Cost Management System (CMS), Employees Time and Attendance Management.

3.5. ORDER INTAKE

The Engineering department is the starting point of an order. The customer places an inquiry for a product or a range of products. This enquiry is received by the Engineering department, and tendered. If there is a mutual agreement on due dates, cost and general specifications the customer places the order. There are twelve different ranges of standard products, with a number of standard variants for each range. Due to customer requirements alterations might be required in the design of the end product. Hence the company can be categorised as a 'make-to-order' company.

When the order is confirmed by the customer a procedure is triggered which involves the Engineering and the Production Control departments. Based on the due date, the customised manufactured and purchased parts will be engineered and specified. The next step is the release of the orders to the shop floor and the suppliers. The time allowed to engineer the new parts and specify the end product is usually six to eight months. During this time all the components for the end products are expected to be manufactured and purchased.

3.6. DEMAND MANAGEMENT

The master production schedule plans are done on a medium (four months) to long term (two years) basis. The plans are based on forecast and actual demand figures that the Sales and Marketing department develops. The manufacture of the LMT, LSR, YMV, RO, and ESR is initiated based on forecast demand. This is due to the repetitive nature of these switchgears. The other products are made only on a firm customer's order. As mentioned before each of the gear ranges can be split down into a number of gears that differ in rating capacity and operation method.

In case the forecast is inaccurate in terms of type of a specific gear or, quantity then with the actual orders intake the production rate is adjusted. The planned and ready

for release orders are cancelled and the already open orders are re-scheduled. However, it is estimated that there is flexibility to produce six switchgears of one range, when the forecast changes to actual demand in very short notice. The orders for the additional parts are released as short dated and high priority orders in order to meet the customer's due date.

The Rough Cut Capacity planning is done based on the "Capacity Planning using Overall Factors" (CPOF) method (Vollmann *et al.*, 1985). The model takes into account demonstrated capacity and the future requirements are assessed.

3.7. MATERIAL REQUIREMENTS PLANNING

The MRP module runs every weekend using the net change approach. The horizon is six months. The rules for aggregated material plans are based on the 'ABC' classification of components. The general rules applied are:

- 1) 'A' class parts corresponding to six to twelve batches per year,
- 2) 'B' class corresponding to six batches per year,
- 3) 'C' class corresponding up to six batches per year.

Additionally, other rules such as minimum/maximum size, standard and multiple batches, are applied. A number of purchased parts is controlled with a two bin system. Raw material, steel aluminium plates, castings and bars, are controlled by MRP. MRP plans account for 150,000 parts that exist on the system of which on average 50,000 are used at any time. Customised features of the specific MRP system are automatic order re-scheduling and scheduling of planned orders six weeks before their date of release. The number of orders released on the shop floor every week is on average 800.

3.8. SHOP FLOOR

The shop floor consists of four main areas namely the machine shop, the fabrication shop, the medium voltage assembly shop and the high voltage assembly shop. It extends in an area of 260,000m².

3.8.1. MACHINE SHOP

The machine shop consists of a number of CNC machines for turning, flexible machining centres and conventional machines for drilling, milling, grinding and boring. The components produced are shafts, pins, washers, nuts and bolts, turned castings, contacts, covers, links and levers, which vary in size depending on the requirements of the product. The parts produced by this area are mainly used in the circuit breakers and mechanisms of the end products.

3.8.2. FABRICATION SHOP

The fabrication shop is split into two major sites, the heavy and light. The heavy site manufactures fabricated steel and aluminium parts (plates over 4mm thick) for the high voltage products. The machines that constitute the heavy fabrication shop are conventional in their majority including milling, drilling, boring, bending, and grinding machines and a number of different presses.

The light fabrication site is used for the manufacture of parts for the medium voltage products (*Appendix I*). The components produced are used for the framework of the switchgears, side sheets, angles, doors, and switch panels.

The components manufactured are divided into two categories. There are the simple articles (components) and the nested ones. A nested article is a set of components that are initially produced using steel or aluminium plate on a CNC punching machine. These components are critical to the assembly of a specific end product. For example, a nested article can consist of two side sheets of a switchgear, left hand and

right hand. It can also include angles doors, and parts which will form the framework of the switch panel.

This policy was adopted by the company a few years ago. The components were grouped into nests to achieve the following objectives:

- 1) Reduction of raw materials waste. All of the components of a nest are produced from one sheet of metal.
- 2) Reduction of paperwork, one order required for as many as ten components.
- 3) Effective control and synchronisation of production for the components that constitute a nest.

The machines that constitute the light fabrication site are two CNC punching machines, two press brake machines, welding, grinding and drilling facilities.

3.8.3. ASSEMBLY SHOP

There are two shops for assembly, one for the medium voltage products and the other one for the high voltage products.

On the medium voltage site there are five assembly lines for end products; LMT and LSR, SMS, RO, ESR, and YMV (*Appendix I*). The parts required are either withdrawn from the stores or they exist as line stock at the place of assembly. The assembly operation for each product consists of two distinct subassemblies; the circuit breaker and the shell of the switchgear.

On the high voltage site there is no on-line stock and the parts are brought from the stores in the forms of kits. A kit contains all the parts, manufactured and purchased, for a specific subassembly. The level of cleanliness is very important in order to prevent malfunctioning of the breakers, and this is one of the major reasons for the non existence of line stock. When the end product is assembled various electrical and

leak tests are performed. The product is dismantled and send to site where it is assembled again.

3.8.4. SHOP FLOOR ORGANISATION

The machines for the machine shop and fabrication shop are organised in a functional layout. Same type machines are grouped together in departments, e.g. milling, drilling, grinding, CNC and Flexible Manufacturing Systems (FMS). Transportation of components is done by using cranes, or bogies.

The layout for the assembly shop is more product focused. There are assembly lines dedicated to the completion of each end product.

3.9. SHOP FLOOR CONTROL

The Shop Floor Control module backschedules the work orders from the due date assigned by MRP. Standard times exist on the system for each operation which are assigned as soon as the routing for a specific part is created. A due date is assigned for each operation in the routing of a batch of components. Due to the fact that Capacity Requirements planning is not used, infinite capacity is assumed at this level. A dispatch list is generated for each workcentre based on the earliest due date. The dispatch list is the schedule on which the production is based.

The paperwork for the orders illustrates the following information:

- 1) The sequence of operations.
- 2) The tooling required for each operation.
- 3) The material required for the components.
- 4) A manual issue sheet if material is required from the stores.

Against each operation a bar code is printed; when an operation is complete the bar code is scanned and the system is updated. This procedure is essential for three main reasons:

- a. Retain visibility on the progress of the order.
- b. Update inventory records as back flashing is used.
- c. Update the accounting records.

When an operation is finished the batch will be either moved to the next workcentre or stored until the start of the next operation.

The Shop Floor Control module does not account for assembly operations. The assembly shop receives a list containing the orders that have to be assembled from MPS and the specifications for the assembly from the Engineering department. The assembly operations for a customers order can start only when all parts are available. The confirmation about the availability of components comes from MRP.

Delays in the manufacturing operations and receipt of purchased items results in the creation of backlogs. The lateness is mostly related to long lead time components required for the assembly of the end product. Due to the fact that the shop floor schedules assume infinite capacity, and do not deal with the backlog, the flow of orders on the shop floor is conducted as planned. The result is that the inventory of short lead time components keeps on increasing because they are not actually required, due to the backlog. The company realised the need to reduce and control effectively the inventory levels of these short lead time parts and a two-bin inventory system with some elements of a Kanban system was introduced. The components used for the new inventory control system were initially nested components. These parts were selected, due to:

- a) Their short lead times.
- b) Their importance in the assembly of the end product.
- c) The relative simple and standard routing.
- d) The fact that these parts are not affected by the customer's specifications.

The manufacturing orders for the nested components are received by the Assembly shop, instead of fabrication. These orders are put on hold until they are required for building the end product. In order to maintain visibility a new "phantom" workcentre

is added at the beginning of their routings. The orders are received by the "phantom" workstation as soon as they are released.

When the assembly of a customer's order can begin the inventory of the nested components is checked. If the inventory is not sufficient for the current demand then a number of orders for the nested components is released to the fabrication shop. These finished products are expected to be received in a week's time since the established lead time for the parts is five days. Discrepancies, however, occur, resulting in delays for these crucial to the end product items. Due to this fact a safety stock is maintained to avoid any shortages that might occur.

3.10. DISCUSSION

Reyrolle Switchgear, falls into the category of the traditionally organised companies that were discussed in *Chapter 2*.

The implementation of MRPII was not as successful as it was anticipated. Although the use of the system facilitated the information flow within the company the traditional practices did not change. The use of the CAPM system benefited the company in terms of inventory reduction. However, at the shop floor level the process focused organisation did not change and hence no reduction in lead times was achieved.

The complexity of the existing situation is due to a number of reasons. There is lack of ownership and accountability on the shop floor, lack of distinction in terms of product requirements and increased number of parts that the databases have to account for. There is also lack of initiative and control at the shop floor level. At present it is difficult to establish the exact reasons why the facility is not effective and even a sophisticated system like MRPII cannot provide the answers. Additionally, due to the variability that governs production, the implementation of pull systems is difficult.

According to Burbidge (1989), process based organisation is obsolete and it has been superseded by product based organisation. The benefits of the product focused organisation were analysed in detail in *Chapter 2*. In order to gain shop floor control the company started considering a change program which was initiated by a shop floor re-organisation.

In the subsequent chapter the creation of a manufacturing cell will be presented. The cell was designed in such a way that established visibility and simplistic control allowing the use of a pull system. The implementation of a pull system needs a deterministic environment as it was discussed in *Chapter 1*. The deterministic nature can be broken down into two major components, demand and production response. The demand for articles used for the existing "Kanban" system was easy to be determined since they were standard parts critical to the built of the end products. The response of the manufacturing site however, was not reliable due to the aforementioned reasons.

CHAPTER 4. A COMPONENT BASED CELL

4.1. THE SHEET METAL SHOP

The number of components that is produced in the sheet metal shop is 30,000. The components in their majority are used by the medium voltage site, but there is a limited number of parts produced which are used for high voltage products. Although the variety is high these components are produced from the same raw material, mainly steel plates whose thickness does not exceed 4mm. The components produced are side sheets, angles doors and frames. These components are geometrically similar and share the same operations. Most of sheet metal work, the plates are punched, bend, drilled, welded and ground if required. In the bill of material structure of the product they are usually level two, hence the finished parts are used directly for assembly.

The parts produced have relatively short lead times, although the times for manufacture are not established as the existing methods of operation are governed by priority rules which are changing constantly.

The layout of the sheet metal shop followed the functional layout rules: CNC punching machines grouped together, press brake machines, drilling, welding and grinding. The production flow had not been taken into consideration, thus increasing the Non Value Adding (NVA) activities. In order for each operation to start the operator had to get the drawing and any specialised tools. This was an action which increased the lead time and could be avoided. A bar coding system was to be implemented so that with the completion of each operation the CAPM system would be updated. This was an action that would add cost (time spent to complete transaction) but no value to the components.

Every workstation was working based on the list provided by the system. The target was to complete each operation by the predetermined due date rather than finishing the components on time. The difference between the two was significant as the priority of the orders on the various work-to-lists were different. In simple terms the workstations were operating on different schedules. This resulted in WIP increase as the orders had to wait for their turn to be processed between the various operations.

4.2. DATA COLLECTION

The data used for the formation of the cell were bill of materials structures, production routes, set-up and run times, data related to machines capabilities, planned lead times, and existing layout of machines (*Appendix I*). The data related to production routes were directly downloaded from the MRPII databases. Top level part numbers were used which represented a number of different assemblies for the following products: LMT, LSR, YMV, RO, ESR, and SMS.

The original data was split into components that were manufactured in the fabrication area and components manufactured in the machine shop area. The data concerning the fabricated components were used for further evaluation. The Line Analysis methodology was used to determine the arrangement of the machines in order to achieve the optimum material flow.

4.2.1. EXISTING MATERIAL FLOW

The parts used for the evaluation of the existing system were components which were fully manufactured by the sheet metal shop and components that were only partially processed and subsequently visited other areas of the factory. The production routings used were approximately six hundred. In order to simplify the representation of the material flow, workcentres which were not part of the light fabrication site were grouped under the appropriate codes. The data were analysed using Excel 4.0 and *Figure 4.1* displays the From-To analysis of the initial material flow.

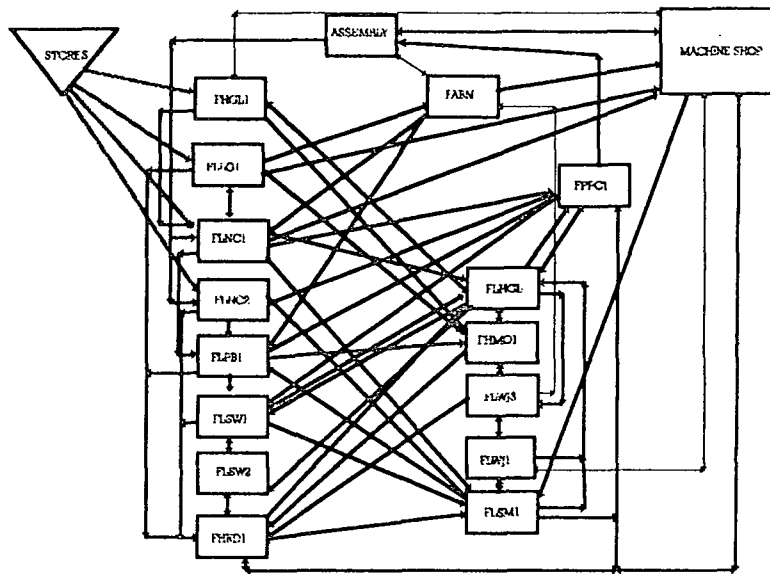
The information from the From-To chart was used to develop a schematic representation of the material flow at the light fabrication area (*Figure 4.2*). This top level view reveals that the production requirements were not used in the past to simplify the production moves and arrange the layout accordingly.

Figure 4.1. From-To analysis chart.

TO

FROM	A F L M C	A P E T H	A F S U B	A F L M R	F H G L 1	F H M O 1	F L S W 2	F L W J 1	F L W J 3	F L L G 1	FAB N	F L N C 2	F L S W 1	F H R D 1	F L N C 1	F L P M C 1	F L P H G L	F L P B 1	P R E S S E S	E N D	M/ S H O P		
AFLMC																				1			
APETH																				1			
AFSUB																				2			
AFLMR										3		7			2								
FHGL1						1						5			5			1		19	1	7	
FHMO1					1									9									
FLSW2													1	3							1	1	
FLWJ1																2	40					1	
FLCEL														1						9			
FLLG1						1					12	5		1	65	2			8	111	16	44	
FABN				1						3				1					11				
FLNC2														6		41	1	3	52	5	3	7	
FLSW1							10							3		9	14	1				8	
FHRD1							20									4	4	4	16	4	13	11	
FLNC1										2					11		15	2	3	47	8	2	7
FLSM1													2	4			3	53	37	8	4	15	
FPPC1	1															1					103	4	
FLHGL							2		9					7	4		1	27		2	15	4	35
FLPB1						1							10	2		25	28		4		29	46	
M/SHOP		1	1					6		2						4	14		8	63	357	425	

Figure 4.2. The Schematic diagram of the material flow at the light fabrication shop.



4.2.2. SIMPLIFICATION OF THE MATERIAL FLOW

The next step of the methodology is the identification of the main production routes within the area under evaluation. The production routes were identified and simplified in order for the major routes to be revealed. The initial number of six hundred routings was reduced down to two hundred. The rule for the simplification was:

The routings included should visit at least two of the sheet metal shop machines subsequently.

The reason for this rule was that the issue under evaluation was the material flow within a specific area. Unless a part was processed by two machines in the same area there was no material flow. Although parts that visit the specific area for just one operation have a major effect on the capacity of a specific machine, in terms of material flow they cannot contribute to this analysis.

In order to identify the major routes the original data was re-organised. The main issue was the sequence of operations. For each part number the operation sequence

was identified and a matrix was created which consisted of six hundred routings. After the simplification, the two hundred routings (approximately) were analysed. In *Figure 4.3* a sample of the routings is displayed. The last figure on each line represents the number of appearances of the routing in the matrix. *Figure 4.4* is the schematic representation of the major routings that were identified. Fifteen different major routings were identified:

1) FLNC1	2) FLPB1	FLSM1	FLHGL		
1) FLNC1	3) FHRD1	FLPB1	FLSM1	FLHGL	
1) FLNC1	4) FLSM1	FLPB1			
1) FLNC1	4) FLSM1	5) FLHGL			
6) FLPB1	FLSW1	FLSM1	FLHGL		
7) FLSW1	FLSM1	FLWJ1	FLHGL		
8) FLNC2	FLPB1	FLSM1	FLSW1	FLSM1	FLHGL
8) FLNC2	FLPB1	9) FLSW2	FLSW1	FLSM1	FLHGL
10) FLNC1	FLSM1	FHRD1	FLPB1	FLSM1	FLHGL
10) FLNC1	11) FLPB1	FLSM1	FLHGL		
12) FHRD1	FLSW1				
12) FHRD1	13) FLHGL	FLSM1	FLHGL		
14) FLPB1	FHRD1				
14) FLPB1	15) FLSM1	FLHGL			

(The change in the routing number indicates another possible route that the parts follow).

There is a substantial reduction in complexity from the initial schematic representation of the routings. A line flow has not yet been achieved however. The distortion is caused by the repeated use of a single work centre which is the FLSM1 (sheet metal work).

In order to simplify the flow, the above routings were combined, and identical machine sequence patterns were identified. The result of this analysis is shown in *Figure 4.5* and three major routes were identified. The determination of the layout of the machines was based on the most "popular" route that derived from the From-To analysis that followed.

Figure 4.3. First pass for the identification of the simplified routings.

OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4	OPERATION 5	OPERATION 6	OPERATION 7	NUMBER OF IDENTICAL ROUTINGS
FLLG1	FLNC1	FLPB1					25
FLNC2	FLPB1	FPPC1	M/SHOP				16
FLNC1	FLPB1	M/SHOP					9
FLLG1	FABN	FLPB1					8
FLNC2	FHRD1	FLPB1	M/SHOP				6
FLWJ1	FLHGL	M/SHOP					6
FLSM1	FLHGL						5
FLLG1	FLNC1	FLPB1	FLSM1	FLHGL	FPPC1		4
FLLG1	FLPB1	M/SHOP					4
ASSEMBLY	FLNC2	FLPB1	FPPC1				3
FHGL1	FLNC1	M/SHOP					3
FLLG1	FLNC1	FLSM1	M/SHOP				3
FLNC2	FLPB1	FLSM1	FLHGL	FPPC1			3
FLNC2	FLSM1	M/SHOP					3
FLWJ1	FLHGL	FLWJ3	M/SHOP				3
FHGL1	FLNC2	M/SHOP					2
FLLG1	FLNC1	FLPB1	FLSM1	FLHGL	FLSW1	FPPC1	2
FLLG1	FLNC1	FLSM1	FLPP2	M/SHOP			2
FLLG1	FLNC1	FHRD1	FLSM1	M/SHOP			2
FLLG1	FLNC1	FHRD1	FLPB1				2
FLLG1	FLNC1	FHRD1	M/SHOP				2
FLLG1	FLNC2	FLSM1					2
FLLG1	FLNC1	M/SHOP					2
FLNC2	FLPB1	FLSW1	FPPC1				2

Figure 4.4. Schematic diagram of the simplified routings.

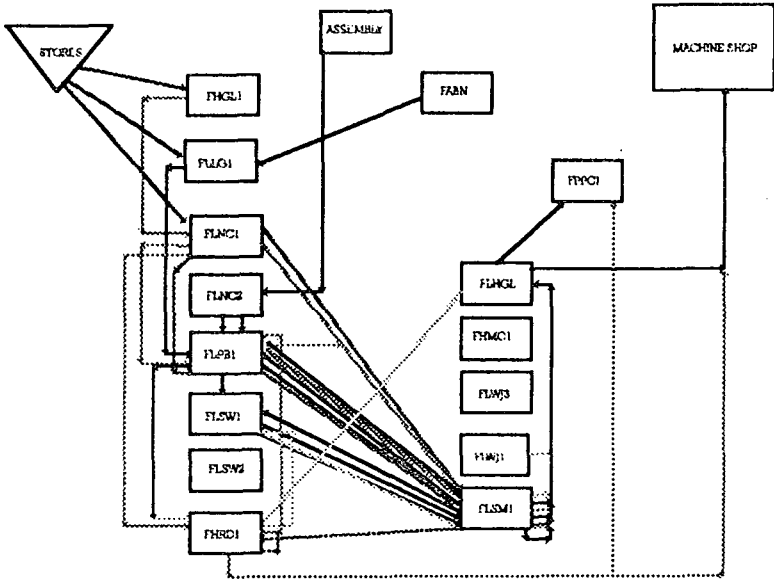
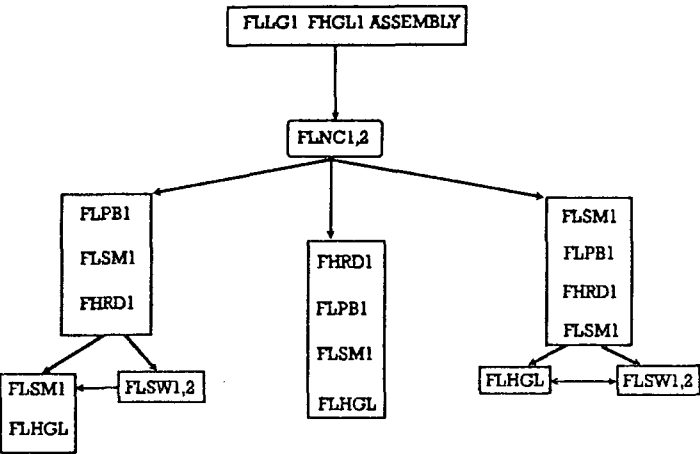


Figure 4.5. The generic routing identified for the light fabrication shop.



4.2.3. FROM-TO ANALYSIS

The objective of the From-To analysis at this stage was to determine the sequence of machines that will maximise the one-direction flow within the fabrication cell. The starting point for the analysis was the formation of a From-To matrix. The sequence of the machines in the matrix was based on the existing layout of machines (*Figure 4.6*).

The top row of the matrix represents the receiving workcentre, whereas the first column is the sending workcentre. This matrix reflects all the discrepancies in the flow of parts. All numbers below the diagonal line represent operations that disturb the forward flow of parts. The objective is to create a matrix that the section below the diagonal will be equal to zero. This, however, is not always possible because of the machine duplication that might be required.

The data obtained from the matrix (*Figure 4.6*) reveal that 123 out of 648 operations have to move backwards to be completed. This represents 19% of the total number of operations and thus the existing layout allowed 81% of forward material flow. The "hits" for the "M/SHOP" row and column were not taken into account as it can be considered as a separate area, and parts can flow in and out of the cell at any time. Additionally, the column named "LAST", which represents all the final operation in the routings, was not included in the calculation because the numbers against the workcentres in this column will not disturb the flow.

Based on this matrix, the following empirical method was used to identify the best sequence:

Starting with the workcentre on the sending department column that had the biggest number of hits the most frequent receiver (TO) was identified, again based on the number of hits against it. For example from the CNC punching workcentres (FLNC1 and FLNC2) the most frequent receiver is the press brake machine (FLPB1). The

same procedure was followed until there was no receiver to be found. After the first pass the sequence of the machines was: FLNC1 FLNC2, FLPB1, FLSM1, FLHGL, FLWJ3. The "hits" against the other machines and the flow between the various workcentres would determine their place in the sequence.

It was made apparent from the schematic diagram (*Figure 4.4*) and the representative routings that the FLSM1 workcentre caused a great disturbance in material flow. Due to this fact, a number of operations were checked on site to identify the reasons why parts had to flow in and out of the specific station repeatedly. It was found that in many cases when a plate was punched the components had to be separated and actually be cut from the original plate. In order to do that the plates were sent down the line to the sheet metal work workstation and then returned back to the press brake. This rule applied to every routing that included the FLSM1 workcentre after the CNC punching machines. This operation, however, did not require special skills so anyone in the cell could do it. A number of cutting tools was required, to enable the operators to cut the articles. The only issue, however, was that although the cutting operations were detectable, sometimes the parts required grinding, and that was not always visible from the way the routing was specified. This again was an operation that could be done by any operator in the cell provided that the tools were available.

Taking into account these observations and after a number of iterations the best sequence of machines was established. *Figure 4.7* displays the sequence of machines. The forward flow for the new layout was between 92% and 96% of all operations. The difference (4%) was due to the fact that it was not possible to determine how many clean and grind (FLHGL) operations required special skills and tools. The rule was that unless it was the last operation (the parts were cleaned in order to be painted, silver plated, or zinc plated), it was an operation that could be done by the operator at the previous workcentre.

As mentioned before, the procedure that was used to determine the best sequence of machines is empirical. In order to confirm the results obtained, mathematical modelling was used. The above problem can be considered as a transportation problem which is dealt using dynamic programming techniques.

Figure 4.6. From-To matrix of the before the Line Analysis

TO	FROM	FHGL1	FLLG1	FLNC1	FLNC2	FLPB1	FLSW1	FLSW2	FHRD1	FLSM1	FLWJ1	FLWJ3	FLHGL	FPPC1	M/SHOP	LAST
		1	1	1	2	1	1	2	1	1	1	3	1	1	P	T
FHGL1			0	5	5	0	0	0	0	0	0	0	1	0	7	1
FLLG1		0		65	10	8	0	0	1	2	0	0	0	0	44	16
FLNC1		0	2		0	47	0	0	11	15	0	0	3	2	7	2
FLNC2		0	0	0		52	0	3	6	41	0	0	3	1	7	3
FLPB1		0	0	0	0		10	5	2	25	0	0	0	28	46	29
FLSW1		0	0	0	0	0		10	3	9	0	0	1	14	8	0
FLSW2		0	0	0	0	0	1			0	0	0	0	0	1	1
FHRD1		0	0	0	0	16	0	20		4	0	0	4	4	11	13
FLSM1		0	0	0	0	37	2	0	4		0	0	53	3	15	4
FLWJ1		0	0	0	0	0	0	0	0		0	0	40	2	1	0
FLWJ3		0	0	0	0	0	0	2	0	0		0	0	0	10	2
FLHGL		0	0	0	0	15	7	2	4	1	0	9		27	35	4
FPPC1		0	0	0	0	0	0	0	0	1	0	0	0		4	103
M/SHOP		0	2	0	0	8	0	0	0	4	6	0	0	14		357

Figure 4.7. From-To matrix after the Line Analysis.

TO	FROM	FHGL1	FLLG1	FLNC1	FLNC2	FLPB1	FLSW1	FLSW2	FHRD1	FLSM1	FLWJ1	FLWJ3	FLHGL	FPPC1	M/SHOP	LAST
		1	1	1	2	1	1	1	1	1	2	1	1	1	1	T
FHGL1			0	5	5		0	0	0	0	0	0	1	0	0	7
FLLG1		0		65	10	2	8	1	0	0	0	0	0	0	0	44
FLNC1		0	2		0	15	47	11	0	0	0	0	3	0	2	7
FLNC2		0	0	0		41	52	6	0	3	0	0	3	0	1	7
FLPB1		0	0	0	0		37	4	2	0	0	0	0	0		
FHRD1		0	0	0	0	0	16		0	20	0	4	4	0	4	11
FLSW1		0	0	0	0	0	0		10	0	9	1	0	14	8	0
FLSW2		0	0	0	0	0	3	1		0	0	0	0	0	1	1
FLWJ1		0	0	0	0	0	0	0	0		0	40	0	2	1	0
FLSM1		0	0	0	0	0	0	0	0	0		53	0	3	15	4
FLHGL		0	0	0	0	0	15	4	7	2	0	1		9	27	35
FLWJ3		0	0	0	0	0	2	0	0	0	0	0		0	10	2
FPPC1		0	0	0	0	0	0	0	0	0	1	0	0		4	103
M/SHOP		0	2	0	0	0	8	0	0	0	6	4	0	0	14	425

4.3. DYNAMIC PROGRAMMING

Dynamic programming is an optimisation technique. What we usually mean by optimisation is finding the best solution to some problem from a set of alternatives. Mathematical models of situations or phenomena which exist in the real world have been developed to solve various optimisation problems (Nemhauser *et al.*, 1989; Cooper *et al.*, 1981; Williams, 1978).

Dynamic programming is a way of looking at a problem which may contain a large number of interrelated decision variables so that the problem is regarded as if it consisted of a sequence of problems each of which required the determination of only one (or a few) variable. What is done in reality using the mathematical models is solving n single variable problems instead of one n -variable problem. The transformations carried out for the simplification of a problem are based on the principle of optimality. It was initially enunciated by Richard Bellman and it has an intuitively obvious basis. The principle of optimality is:

An optimal policy has the property that whatever the initial state and the initial decision are, the remaining decisions must constitute an optimal policy with respect to the state which results from the initial decision.

4.3.1. THE TRAVELLING SALESMAN PROBLEM

The travelling salesman problem exemplifies a whole class of optimal scheduling problems which are difficult to solve. A statement of a problem is as follows.

A salesman is required to visit, once and only once, each of n different cities starting from a base city and returning to this city. What path minimises or maximises the total distance travelled by the salesman?

The obvious way to solve the problem is to calculate every possible permutation of n cities and calculate the sum of distances for each permutation or the travelling salesman's tour. It is clear that for n cities there are $n! (1 \times 2 \times \dots \times n)$ permutations.

For modelling purposes the origin of the travelling salesman is 0 . Now suppose that at a certain stage of an optimal tour starting at 0 , one has reached a city i and there remain k cities j_1, j_2, \dots, j_k to be visited before returning to 0 . It is clear that the tour is optimal when the path from i through j_1, j_2, \dots, j_k in some order and back to 0 , must be of minimum or maximum length.

The following function is defined:

$g_k(i; j_1, j_2, \dots, j_k) \equiv$ length of a path of minimum/maximum length from i to 0 which passes, once and only once, through each of the remaining k unvisited cities j_1, j_2, \dots, j_k .

If we obtain $g_n(0; j_1, j_2, \dots, j_n)$ the travelling salesman problem will have been solved.

We also define d_{ij} as the distance between city i and city j .

Using the notation introduced and the principle of optimality the following recurrence relations are obtained (Nemhauser *et al.*, 1989; Cooper *et al.*, 1981; Williams, 1978):

$$g_k(i; j_1, j_2, \dots, j_k) = \min_{1 \leq m \leq k} / \max [d_{ij_m} + g_{k-1}(j_m; j_1, j_2, \dots, j_{m-1}, j_{m+1}, \dots, j_k)] \quad i=1, 2, \dots, n$$

4.3.2. THE DEFINITION AND SOLUTION OF THE PROBLEM

The arrangement of the machines at the fabrication shop can be regarded as a dynamic programming problem and in particular as a "travelling salesman" problem. What is required is the sequence of machines that will achieve the maximum flow. In this case the cost of the original travelling salesman problem is translated as the number of parts travelling from one machine to another.

The mathematical model can be formed as follows.

The travelling route consists of ten stations (ten workcentres of the light fabrication). The origin of the "salesman route" is a phantom workcentre which can be the raw material stores or any other workcentre in the factory. The route starts and finishes at that phantom workcentre. The code 0 is assigned to it for conformity to the original model. The main reason for this assumption is that the fabrication cell is not independent from the other areas of the factory. Parts can start and finish in this area or they might be processed on a number of machines and then be processed elsewhere. The codes assigned for the following workcentres are:

WORKCENTRE	CODE
FLNC1 & FLNC2	1
FLSM1	2
FLPB1	3
FHRD1	4
FLSW1	5
FLSW2	6
FLWJ1	7
FLSM1	8
FLHGL	9
FLWJ3	10

The two CNC punching machines were grouped under the same code because there is no interaction between the machines. Although there might be occasions where a part will have to visit the same machine for more than one time, for simplification reasons we assume that a component visits a machine once.

The function of the mathematical model is as follows:

$$g_k(i; j_1, j_2, \dots, j_k) = \max_{1 \leq m \leq k} [d_{ij_m} + g_{k-1}(j_m; j_1, j_2, \dots, j_{m-1}, j_{m+1}, \dots, j_k)] \quad i=1, 2, \dots, 10, \\ k=1, 2, \dots, 10$$

For $k=1$ $g_1(i; j_1) = d_{ij_1} + d_{j_1 0}$ $j_1 = 1, 2, \dots, 10$ $j_1 \neq i$

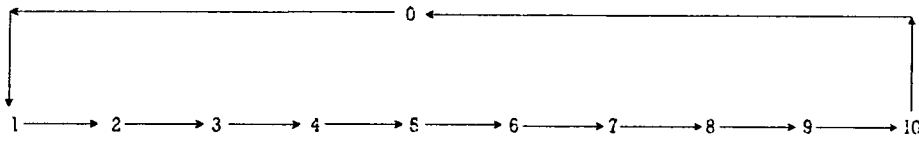
For $k=2$ $g_2(i; j_1, j_2) = \max(d_{y_i} + g_1(j_1; j_2), d_{y_{j_2}} + g_1(j_2; j_1))$ $i=1, 2, \dots, 10$ $j_1, j_2 \neq i$

For $k=10$

$$g_{10}(0; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10) = \max[d_{01} + g_9(1; 2, 3, 4, 5, 6, 7, 8, 9), d_{02} + g_9(2; 1, 3, 4, 5, 6, 7, 8, 9), \dots, d_{09} + g_9(9; 1, 2, 3, 4, 5, 6, 7, 8)] =$$

$$= \max\{364 [g_9(1; 2, 3, 4, 5, 6, 7, 8, 9, 10)], 254 [g_9(2; 1, 3, 4, 5, 6, 7, 8, 9, 10)], \\ 200 [g_9(3; 1, 2, 4, 5, 6, 7, 8, 9, 10)], 253 [g_9(4; 1, 2, 3, 5, 6, 7, 8, 9, 10)], \\ 234 [g_9(5; 1, 2, 3, 4, 6, 7, 8, 9, 10)], 253 [g_9(6; 1, 2, 3, 4, 5, 7, 8, 9, 10)], \\ 253 [g_9(7; 1, 2, 3, 4, 5, 6, 8, 9, 10)], 245 [g_9(8; 1, 2, 3, 4, 5, 6, 7, 9, 10)], \\ 202 [g_9(9; 1, 2, 3, 4, 5, 6, 7, 8, 10)], 246 [g_9(10; 1, 2, 3, 4, 5, 6, 7, 8, 9)] \}$$

The best solution (maximum) is the sequence associated to the maximum of the group of values developed for $k=10$. The maximum of the group is 364 and the associated sequence is the following:



The results obtained from the mathematical modelling are in agreement with the empirical methodology.

4.4. PRIORITY AND MATERIAL FLOW RULES

The parts used for determining the sequence of machines were not just sheet metal work but parts that originated from other parts of the factory and were partially processed at this area. The cell as part of the factory is not an independent unit so it should be integrated based on the overall needs.

Acknowledging the fact that other parts may be processed, a set of priority and material flow rules should be established so that production will be conducted in an organised way.

One of the objectives for the creation of the cell was to achieve one week lead time for the components manufactured by the cell. In order to do this the queuing times had to be eliminated and ensure that when a batch is available at a machine it would be processed as quickly as possible. The priority assignment of the cell owned parts was based on the "First-in First out" (FIFO) rule. A coloured card would accompany every order entering the cell, the colour indicating the day it was released. Since all orders released in a day would be expected to be completed within five days, no sequencing of the orders was necessary. At the end of the five day period all the coloured cards should be returned to the foremen office, who would subsequently attach the cards on new orders. When some of the cards were missing some orders were late. Each individual case would be dealt separately, based on the reasons of the delay, so that the order would be completed without out any further delay.

The priority for the parts that were not owned by the cell would be assigned by the Shop Floor Control module. A due date was assigned for each operation and the processing would be based on the earliest due date rule. Due to the fact that the components owned by the cell should have priority over the foreign parts, a temporary storage space was allocated for every machine. The foreign parts would be temporarily stored there until the cell components were processed. The storage area would provide visibility over bottleneck machines, enabling operators and supervisors to identify the problems quickly and take the necessary actions.

An additional NVA for the cell was the time spent to obtain the drawings corresponding to the parts from the drawings store. The procedure before the creation of the cell was that every operator would get a copy of all the drawings before the processing of the batch. In order to eliminate the time spent, a complete set of drawings for each component would be prepared and accompany the order though the cell. In case there were two orders for the same component still "live" in the cell, a second set of drawings was always available. This, however, was unlikely to happen due to the batch sizes.

The tools required to complete every operation were stored in cabinets next to the machines. If special tools were required they were withdrawn from the tool stores. This was a policy that was in place before the creation of the cell.

4.5. FEEDBACK TO MRPII

Feedback was necessary in order to integrate the cell into the already existing MRPII system. The first data change concerned the MRP planned lead times. An ongoing exercise started and planned lead times were changed to five days for all the parts owned by the cell. The second stage of updating related to the SFC module and the cost aspects of production. It has already been mentioned (*Chapter 3*) that the bar coding system was about to be implemented. The completion of every operation would be signalled to the system through the bar code scanning. This feedback would update the account records (WIP value), and enhance visibility of the location of the order. In the case of the cell, however, the continuous updating of the SFC module through bar coding was superfluous and an NVA, since it was ensured that enhanced visibility on the orders progress was established. It was imperative, however, that an MRPII user should be able to know that an order was in the cell area.

A new workcentre was specified on the system with the FLCEL code. This in reality was a group of the workcentres that constituted the cell. The SFC scheduling was done for this workcentre only and not for every operation that the part required. The paper work for each order included displayed every operation in order to conform with the quality standards.

The new routings specified for the cell components consisted of only one operation, so the bar coding was done only once (*Appendix I*). The instructions for manufacture included the proper sequence of operations with all the details required.

In terms of costing, when an order was released to the cell a certain WIP value was assigned to it related to the components. When the order was completed the total value of the batch was assigned to it.

In terms of set-up run and queue times, standard times were assigned related to the batch sizes. The standard times ensured that the total SFC lead time would not exceed five days.

4.6. DISCUSSION

The parts produced by a manufacturing facility can be classified as repetitive, parts that are manufactured in less regular intervals, or customised. Focus should be placed on standard components whose demand is predictable. The predictability and stability of demand facilitates the use of a pull system. In order to establish a pull system the processes should be reliable and capable, lead times should be established and as short as possible. From the process point of view, a cell should be able to deliver parts in a predetermined time and at the required quality. Using a pull system for repetitive components means that these parts will no longer be controlled by MRPII (Flapper, *et al.*, 1991; Hegstad, 1990). The benefits gained by reducing the number of parts that are controlled by the MRPII system are related to the reduction in complexity achieved.

A pull system can be used in two forms; Kanban, and two bin system. Two bin system should be used for low value components, such as pins, nuts, washers, etc., which should be produced or bought in, in batches and when the inventory falls below a certain point, new batches should be ordered. Kanban should be used for higher value items (mainly 'A' class parts, or critical components) which are produced in small quantities (ideally batches of one) to meet just-in-time the demand of the end product (Miltenburg *et al.*, 1991; Shah, *et al.*, 1990; Silver, *et al.*, 1985; Wild, 1989).

The pull systems are distinguished for their precision in terms of timing, quantity and quality. This achievement is mainly due to the distributed nature of control they establish. Distribution lowers the complexity and offers visibility over the day to day activities. Many researchers (Love *et al.*, 1989; Barekat, 1991; Skarpeid, 1991) have discussed the benefits that can be gained from distributed management software systems. The main reason of the success of these systems is the ability to produce realistic plans and schedules and improve flexibility due to the limited number of data they have to account for.

In the following chapter the development of a decision support system for distributed inventory management will be presented. The system was developed to integrate the "Kanban" system used at the Assembly shop which was used to pull the components from the sheet metal shop. The creation of the cell ensured a more deterministic response of the manufacturing site thus making control more feasible and reducing variability.

CHAPTER 5. THE DECISION SUPPORT SYSTEM

The environments that have implemented JIT or principles of JIT define the material requirements for production at the final assembly line. Instead of being a delivery station the assembly is a generator of demand towards the rest of the of the factory, as well as to the suppliers. The Kanban procedure at the assembly shop of Reyrolle Switchgear is the beginning for a final-assembly driven production. The objectives of the system are:

- 1) Reduction in inventories.
- 2) Visual/effective control.

Due to the make-to-order nature of production the variations of the end products are numerous. The variations, however, are related to the way the product is assembled the number and kind of purchased components (relays, bushings, auxiliary switches) and a limited number of in-house manufactured components. For each switchgear the majority of the manufactured parts are identical throughout the various contracts undertaken, or very similar.

The planned lead times for the medium voltage switchgears LMT, LSR, and YMV are 38, 39, 23 weeks respectively. The time allowed for assembly is 3 weeks for every medium voltage product. The planned stacked lead time for manufacture to complete the enclosures for the LMT, YMV, and LSR switchgears is 9 weeks. The average planned lead time of the individual parts is 2 to 3 weeks. As mentioned in *Chapter 3*, the enclosures for each of these switchgears are standard, with a limited number of variations. The components that constitute the enclosures are in their majority fabricated parts and are manufactured on a repetitive basis. These components are manufactured on fixed batch sizes of 10 or 15.

Fifty five components were controlled with the pull system at Reyrolle Switchgear Ltd. The problems that were encountered were; the unreliable manufacturing lead

times, the difficulty in controlling the orders release due to the increased number of components used for the pull system and the excessive paperwork produced by the system for the orders.

An effective pull system could be implemented due to the repetitive nature of components, their short lead times, and the dedicated cell for their manufacture . The considerations that had to be taken into account are; a) accurate forward planning, b) effective inventory control c) flexibility in terms of schedules change.

The MRPII schedules did not reflect the existing situation because of the backlog that developed from the poor performance of the manufacturing site. This resulted in the issuing of orders that were not required. Although the use of the pull system ensured some reduction in inventory, due to the fact that the orders were released by the MRPII the backlog kept on increasing. What was required was a system that could be flexible in terms of rescheduling in order to optimise the inventory of the Kanban components. Rescheduling with MRPII was not possible because all the requirements for the customers orders would be rescheduled.

A pilot system was developed to facilitate decision making and enhance the pull system in use. A Decision Support System (DSS) was developed using the expert system shell Crystal 4.5.

5.1. EXPERT SYSTEMS

Operations Research (OR) techniques have been based on mathematical modelling and statistics since the early 1960's. At that time it was directed towards mathematical solutions to technical physics and chemistry problems with limited effort expended on the commercial aspects of the businesses. In the late 1960's and during the 1970's the effort gradually turned towards the commercial side, dealing with optimisation problems such as economic forecasting, distribution and investment risk. The effort kept on increasing when by the mid 80's it was supported and

complemented by the emerging information technology of Artificial Intelligence (Walters and Schtaklef, 1990).

Expert systems are computer programs that are constructed to do the kind of activities that human experts can do, such as design, compose, plan, diagnose, interpret, summarise, audit and give advise. Expert systems constitute a part of a larger unit which is called Artificial intelligence.

Expert systems can be described at present as high profile, and are widely seen as a useful technique (Rodger and Edwards, 1990). Such views led to the consideration of expert systems as a means of improving production planning and control functions within a large industrial organisation. The functions that can be undertaken by expert systems are planning, scheduling and monitoring stock levels.

5.2. CRYSTAL 4.5

Crystal 4.5 is an Expert System shell which was developed using C programming language. The development of a source code using Crystal is based on the creation of true or false rules. A rule is a sequence of predicates, logical tests which can comprise either of one sentence or can be expanded to a sequence of sub-rules. There is also a number of computational functions, which support the development of a source code. The development of a program can be based either on forward on backward logic depending on the needs of the specific application. Crystal 4.5 has a built in interface to DBASE III. This interface consists of a number of functions similar to those that can be performed using the database, for example create or delete a record, create indexed files write or read information to/from the database.

5.3. THE DECISION SUPPORT SYSTEM'S OBJECTIVES

The objective of the system is to conduct accurate and effective inventory control, according to the principles of JIT. The planning procedure will be done by the user, who will type the information needed by the system. The system will:

- 1) Schedule the next inventory replenishment.
- 2) Calculate how many components are going to be ordered from the fabrication shop.
- 3) Keep accurate inventory records.

The data for the system will be obtained directly from the MPS/MRP database. The information will be stored in database files (DBase III). The inventory replenishment will be conducted on a daily basis. The system based on the feedback from the user will estimate every day the material requirements, in case the production plans are altered. It will monitor the release of orders to the Fabrication Shop and the release of orders in the Assembly Shop in order to estimate the requirements and gather all the data that can be used for a statistical evaluation of the situation. The data in the database are accessed by the expert system shell Crystal 4.5 (*Figure 5.2*). The expert system performs all the calculations and the updating of the database files. Based on the aggregated results and the rules that support the system it will decide on the inventory replenishment.

One of the basic elements of the system is the constant rescheduling of inventory replenishment. The DSS is flexible in order to cope with changes that can be caused from a number of different reasons due to the dynamic nature of the manufacturing environment. The deviation from the original plans is an issue that has a major impact on inventory levels. At the MRP level the constant rescheduling is uneconomical due to the large complexity and long times required. The distribution of planning activities to the shop floor reduces the time span thus enabling the implementation of a more interactive system.

The pilot system was developed to deal with the inventory replenishment of one component. The article (974A1495N) is used in the construction of the LMT switchgear. The lot size for the inventory replenishment is ten. The planning period is four weeks (*Figure 5.1*).

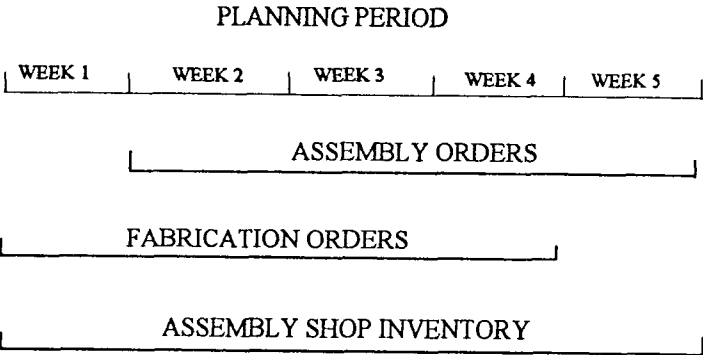


Figure 5.1. Planning horizons of the decision support system.

5.4. THE DESCRIPTION OF THE SYSTEM

5.4.1. THE DATABASE

1) **The assembly-orders file.** Each record is constructed in the following way:

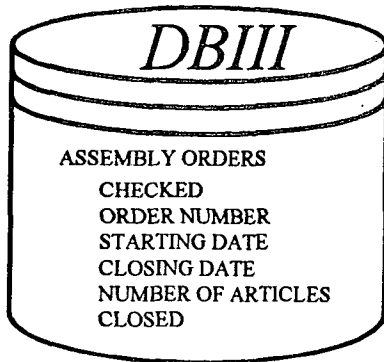
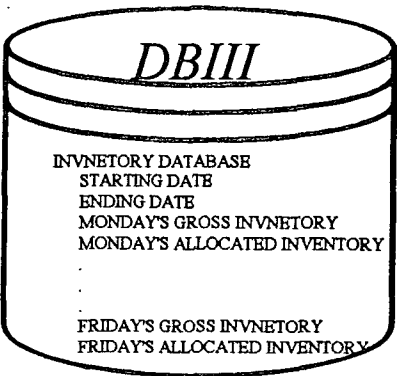


Figure 5.3. The assembly orders file.

- a) Order number: the MRPII order number.
- b) Starting date: the starting date that the planner has defined.
- c) Close date.
- d) Number of articles that are going to be used for the completion of the orders. This is information taken from MRPII.
- e) Two logical fields that keep information on whether the record has been included in previous calculations and indicating when the order is closed. The file is ordered according to the starting date.

2) **The inventory file.** The number of inventoried items is kept on a daily basis. There are four records in a month, one for every week. A record has the following form:



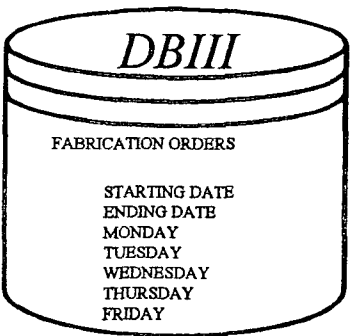
- a) Date of the first day of the week.
- b) Date of the last date of the week.
- c) Monday through Friday gross inventory.
- d) Monday through Friday inventory allocated to orders.

Figure 5.4. The inventory file.

The information about the inventory is kept in two fields. This is done because

the batch is usually not consumed totally, resulting in inventory which should be allocated to other orders without scheduling a new inventory replenishment. The field for the allocated quantity is used for rescheduling in case an order will not start on the predetermined day.

3) **The requirements file.** This file keeps information about how many orders should be released to the fabrication shop. This is done on a daily basis, according to the needs of inventory. The records have the following form:



- a) Date of the first day of the week.
- b) Date of the last day of the week.
- c) Monday through Friday requirements.

Figure 5.5. The fabrication orders file

5.4.2. THE EXPERT SYSTEM

The Expert System Shell Crystal 4.5 is used to retrieve the information from the database files and schedule the fabrication orders release. The schedules are based on the data kept in the inventory file and the actual demand of components from the assembly orders file. In addition, Crystal 4.5 is the interface between the user and the database files in order to make the system user-friendly.

The main menu (*Figure 5.6*) include the following options:

- 1) Add/Update orders.
- 2) Jobs to be started.
- 3) Fabrication orders release/receipt.
- 4) Unexpected inventory replenishment.

5.4.3. ADD/UPDATE ORDERS

As shown in *Figure 5.7* this is the rule to add new orders in the system or update already existing information about them. The new or altered information will trigger the activation of the appropriate rules to estimate the material requirements.

1) ADD

When adding a new assembly order on the system the following information is required: order number, starting date, and number of components needed for the completion of the order. This is done through a relative screen (*Figure 5.8*). Through this screen the user can execute database commands such as add, update and delete or go through every record of the database. The menu is located at the bottom of the screen and the user selects the function either with the arrow keys or with the first letter of the command. When the user types all the information about the new order(s) and quits from this screen the appropriate sub-rules are activated.

The system locates in the assembly orders file the earliest order that has been recently input. Subsequently, it finds all the orders starting the same day and aggregates the

total components needed. The next step is to locate in the inventory file the specific day and check if the net inventory ($\text{net inventory} = \text{gross inventory} - \text{allocated inventory}$) can cover the demand for components. The result of this logical test activates one of the following rules.

a) Release a Kanban order

This rule is activated when the net inventory is not sufficient to cover the demand and inventory replenishment is required. The number of components that are considered for the replenishment is not the actual demand (past and new) but the new requirements minus the net inventory. This is done in order to minimise the inventory that will be kept in the assembly area. The batch size for the components is a restriction for the optimisation of inventory levels. The quantity of the orders released will be a multiple of the batch size and not lot-for-lot. This is the main reason why the net inventory is not always zero, as it should be. The number of orders to be released are estimated by the procedure and the fabrication orders file is updated.

Due to the fact that the lead time is five days, the release of the orders is scheduled a week before the components will be needed at the assembly shop. If there is not enough time for the manufacturing orders to be completed, the system will inform the user (**Figure 5.9**) that the orders should be re-dated. When the fabrication orders file is updated the system returns to the inventory file.

The basic rule for the inventory file is that each day's inventory is dependent upon the previous day's net inventory. Every time a change occurs, the future inventory has to be re-evaluated together with the number of orders released to fabrication.

The changes due to the new requirements added on the system will potentially affect the future scheduled releases and receipts of orders. On a daily basis for the planning horizon the system will re-estimate the new inventory and compare it against the

requirements on each day. The objective is to minimise the inventory at the assembly shop so that all the scheduled fabrication order releases will be under evaluation.

b) Allocate

This rule is activated when the extra requirements can be covered by the net inventory for a specific day. The allocated inventory of that day will be increased by the extra quantity. This results in a change in the net inventory hence the future inventory and the fabrication orders release will be re-evaluated in a similar way as in the Kanban procedure. During the re-evaluation the two rules described will be combined to produce the best results in terms of inventory.

2) UPDATE

The 'Update' rule is selected when the user wants to change already existing data that will influence the system when changes are made to the starting date and/or number of components. The old values will be compared to the new in order to define the changes in the data. The combinations of changes that the system can deal with are shown in *Figure 5.10*. A specific hierarchy was used in order to minimise the computational complexity that will be required if all the variables were to be evaluated at once. The system can accommodate changes which will take place within the permitted planning period.

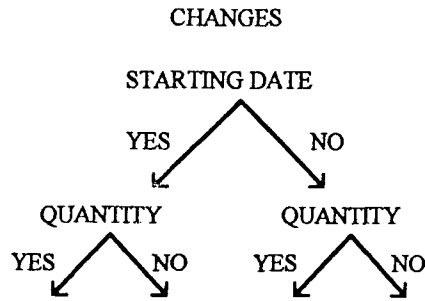


Figure 5.10. Changes that can be performed to the data held by the assembly file.

1) Changes in starting date - quantity the same

The first check concerns the date of the assembly orders. This kind of change has a major impact on the ability of the fabrication cell to respond to any additional parts that might be required. It is very important to establish initially, if enough time is allowed for manufacture. If there is no time for an order to be manufactured then it should be established if the demand can be covered by the existing inventory.

Providing that the timing is right the old quantity of parts required will be subtracted from that day and added to the new date's requirements. Starting from the original date the system will re-schedule the release of the fabrication orders for the planning horizon.

When the net inventory is sufficient, but no cancellation of fabrication orders was possible, the system will assign the new net inventory values and re-schedule the future release of the fabrication order. Although for a limited period of time the inventory will slightly increase due to the fact that the cancellation did not take place the future requirements will be adjusted accordingly.

2) Changes in starting date and quantity

This rule is similar to the one that was described before, the only difference being that the system will account for the quantity changes as well and it will schedule the inventory requirements accordingly.

3) Starting date the same - changes in quantity

The first check will be to verify that the new quantity needed is bigger or smaller from the old quantity. If additional quantity is needed then the system checks if the net inventory of the specific date can cover the demand. If the starting date of the assembly order(s) is at least five working days ahead, the system will just make corrections to the allocated inventory and re-schedule the inventory and fabrication orders files.

If the starting date of the order is earlier (less than five days), the system will evaluate the changes needed to be made for the constraint time period. If there is no need for extra orders it will make the changes. Otherwise, it will inform the user that the fabrication shop can not deliver the components in the given time period. If the new quantity is less than the one originally stored in the data base the system will update the future inventory and fabrication orders files accordingly. Additional checks related to the cancellation of fabrication orders will take place in case they are not required any more.

5.4.4. JOBS TO BE STARTED

This procedure display the jobs that should start on a specific day (*Figure 5.11*). The system will get confirmation from the user whether each one of the orders will start or not (*Figure 5.12-5.13*). For the jobs that will start the total number of components needed will be aggregated and subtracted from the field of that day's allocated inventory.

5.4.5. ORDERS RELEASE/RECEIPT FROM THE FABRICATION SHOP

This is a daily list that displays the number of orders that should be released to the Fabrication Shop (*Figure 5.14*). Information is retrieved from the 'Fabrication orders release' file and the main purpose of this procedure is to give feedback to the user about the fabrication orders. Additionally this procedure displays the number of orders that the assembly shop should receive from the Fabrication Shop on the specific day (*Figure 5.15*).

5.4.6. UNEXPECTED INVENTORY REPLENISHMENT

This is a rule (*Figure 5.16*) to update the inventory records in case there is an inventory replenishment at the assembly shop which was not scheduled or it was not on time. The user types in to the system the amount of components that were received from the Fabrication (*Figure 5.17*). It adds the extra inventory on the relative record and it re-schedules the fabrication orders release when the time allows it.

5.4.7. CLOSE ORDERS

This procedure updates the Assembly orders file when the orders are completed (*Figure 5.18*). The user types in the order numbers (*Figure 5.19*) that are completed and through the interface the relative record is updated.

5.5. INTEGRATING THE SYSTEM

Initially, the integration of the DSS will involve the expansion of the system to schedule the inventory replenishment for all the components controlled by the pull system. Additionally, it can be set to release batches of different sizes in order to optimise the inventory. Due to the fact that the components are used in building different end products, the system can be used separately at each assembly line, thus enhancing distributed planning and control. It is essential that the parts to be controlled by the DSS have established and fixed lead times in order to ensure the

deterministic response of the manufacturing site. The system can be extended to account for bill of materials with more than one levels and co-ordinate the release of orders from the assembly shop rather than from the MRP module. It can also be developed to co-ordinate the assembly activities in relation to the orders release, ensuring that the components will reach the assembly when they are required and at the exact quantities.

In order to reduce the paperwork generated by MRPII the following procedure can be implemented. The articles controlled by the DSS should become phantom items in the bill of materials for the end product. MRP will not generate any requirements for these articles. The decision support system based on the information that it gets from the planners will generate the requirements. MRP can then be triggered to release the orders for the specific articles, which can be kept in separate bill of material lists, as real items. In that way the orders will be received directly by the appropriate area/cell. This feedback to MRPII will ensure that the two systems do not work separately from each other and MRPII will deal with all the cost related issues of the production of Kanban items.

The information held by the databases that support the DSS can be used to produce statistical reports which will determine the performance of the manufacturing system. The information can be used to determine actual lead times and the available capacity of the assembly shop which at the moment are not established. Based on past performance, the planning can be more accurate thus maximising the output of the assembly.

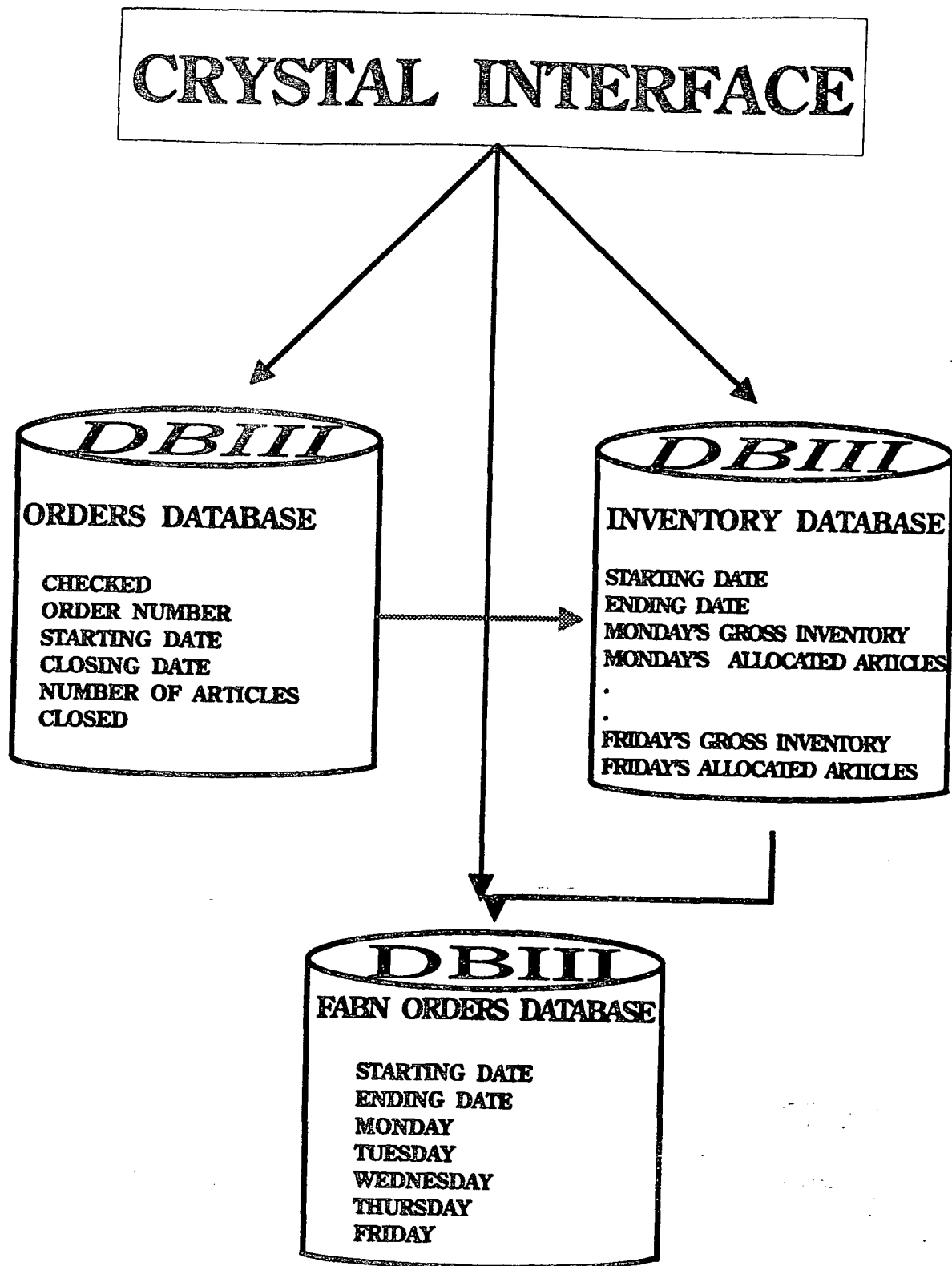


Figure 5.2. The structure of the database.

DECISION SUPPORT SYSTEM FOR INVENTORY CONTROL
UNIVERSITY OF DURHAM

M E N U

- 1) ~~ORDERS TO BE STARTED~~
- 2) ADD ORDERS
- 3) CLOSE ORDERS
- 4) ORDERS TO BE RELEASED/RECEIVED
- 5) UNEXPECTED INVENTORY REPLENISHMENT
- 6) UPDATE
- 7) EXIT

NEI REYROLLE
SWITCHGEAR LTD

(Press F1 for help)

Figure 5.6. The main menu of the Decision Support System.

ADD/UPDATE ORDERS

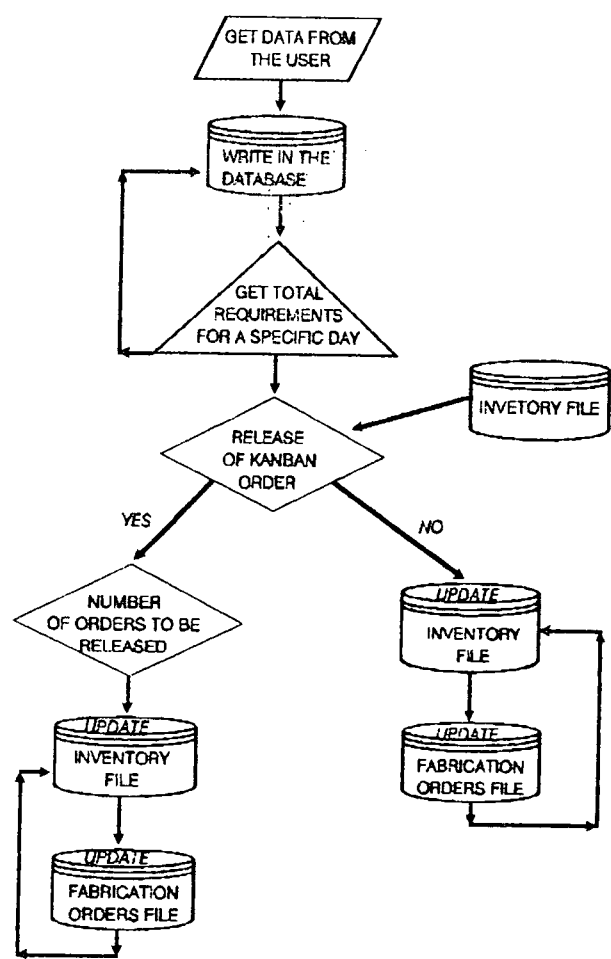


Figure 5.7. The structure of the 'ADD/UPDATE' module.

ORDERS TO BE STARTED AT THE ASSEMBLY SHOP

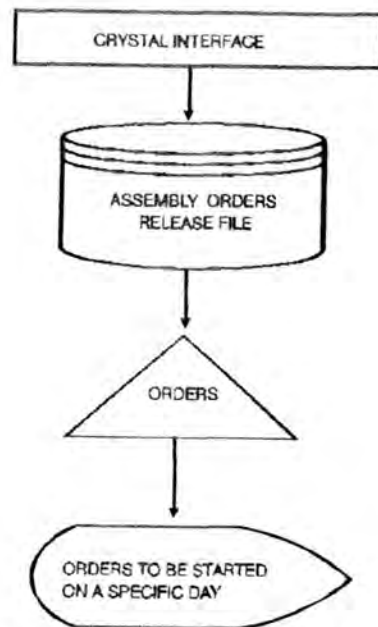


Figure 5.11. The structure of the 'Jobs to be started' module.

The orders to be started today are:			
fordob\$(1)	1	fordob\$(19)	1
fordob\$(11)	1	fordob\$(110)	1
fordob\$(2)	1	fordob\$(111)	1
fordob\$(3)	1	fordob\$(12)	1
fordob\$(4)	1	fordob\$(13)	1
fordob\$(5)	1	fordob\$(14)	1
fordob\$(6)	1	fordob\$(15)	1
fordob\$(7)	1	fordob\$(16)	1
fordob\$(8)	1	fordob\$(17)	1

Figure 5.12. The output screen which includes all the orders that should start on a specific day.

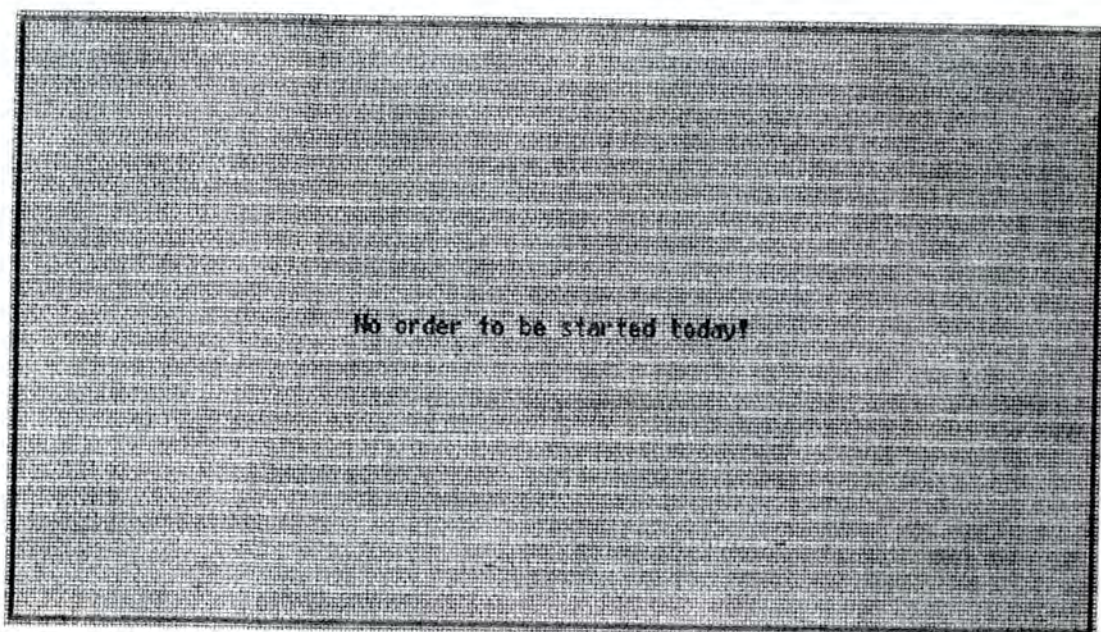


Figure 5.13. This is the output screen when no orders were planned to start.

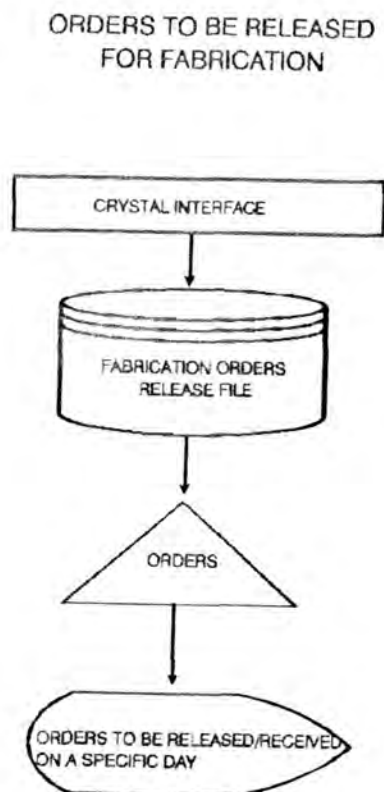


Figure 5.14. The structure of the 'Fabrication orders release' module.

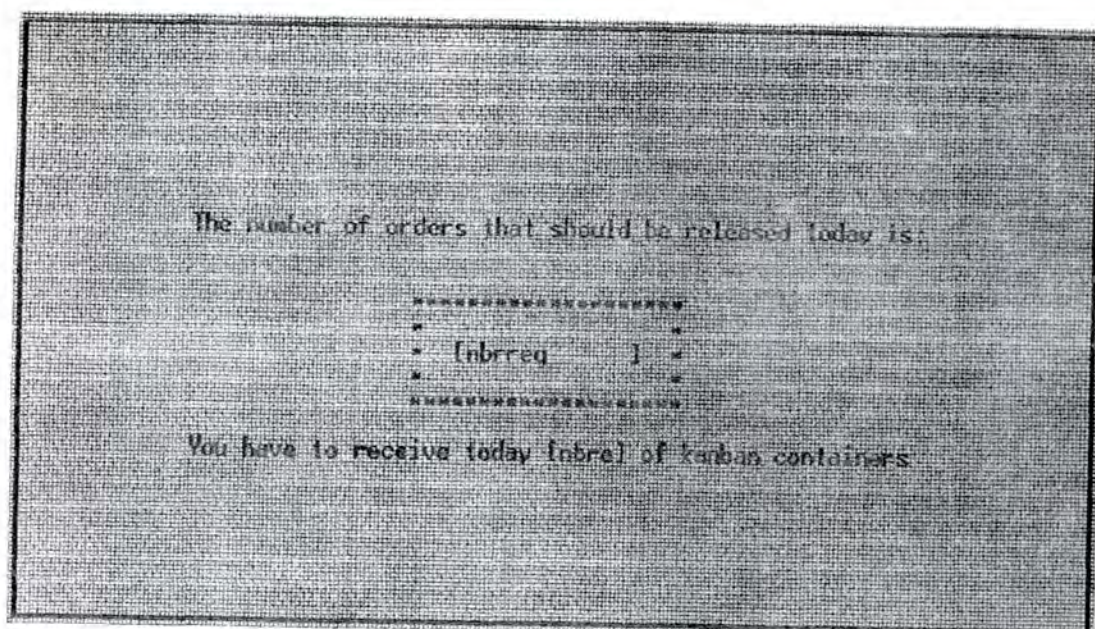


Figure 5.15. The output screen for the number of orders that should be released on a specific day.

UNEXPECTED INVENTORY REPLENISHMENT

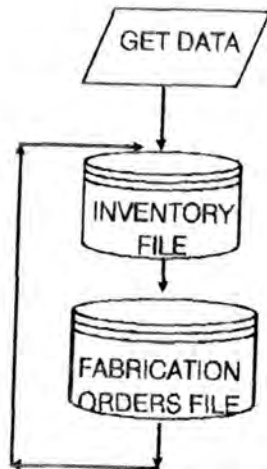


Figure 5.16. The structure of the 'Unexpected inventory replenishment' module.

COULD YOU TYPE IN THE DATE YOU RECEIVED THE ORDER(S)
OR YOU WILL RECEIVE, AND THE QUANTITY THAT YOU EXPECT FROM
FABM

[Redacted input area]

The image shows a computer screen with a dark, textured background. The text is displayed in a monospaced font. The first two lines of text are 'COULD YOU TYPE IN THE DATE YOU RECEIVED THE ORDER(S)' and 'OR YOU WILL RECEIVE, AND THE QUANTITY THAT YOU EXPECT FROM'. The third line is 'FABM'. Below the text is a large, dark rectangular area that has been redacted, likely containing a form for user input.

Figure 5.17. The input screen for the inventory received unexpectedly.

CLOSE ORDERS

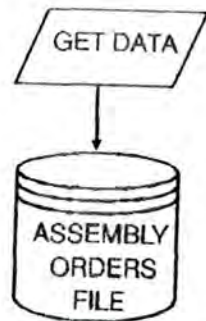


Figure 5.18. The structure of the 'Close orders' module.

Could you pls type in the order number for the orders
that are completed. █

<order\$[0] >	<order\$[10] >
<order\$[1] >	<order\$[9] >
<order\$[2] >	<order\$[18] >
<order\$[3] >	<order\$[11] >
<order\$[4] >	<order\$[12] >
<order\$[5] >	<order\$[13] >
<order\$[6] >	<order\$[14] >
<order\$[7] >	<order\$[15] >

Figure 5.19. The input screen to update the system about which orders are completed.

CHAPTER 6. DISCUSSION AND CONCLUSIONS

The benefits gained with the re-organisation of the light fabrication area at Reyrolle Switchgear Ltd., can be summarised as follows:

Simplified material flow: The rearrangement of machines enhanced the one-way flow (15% increase) and incorporated the components production requirements.

Establishment of discipline: The priority rules (coloured cards), established discipline in terms of priority, taking into account not individual operations but the due date of the order itself. This again, contributed to the simplification of the system, as there is only one target per order to be met and not several, depending on the number of operations.

Visual and problem proofing system: The simplified material flow, and the clarity established by the priority rules enhanced the visibility on potential problems or delays. For example the existence of full temporary storage areas would initiate actions against the potential bottleneck(s) that might develop.

Reduction of NVA activities: The NVA activities that were reduced or eliminated had to do with the transportation of components, withdrawal of drawings, and system transactions. Indirectly due to the organisation of the priority rules the queuing times for the orders were expected to be reduced. This however was not possible to be quantified as the queues before the cell implementation were not measured. The major reason was the variability in terms of queue time due to re-scheduling.

The cell was implemented in June 1992. The production routings for the fifty five Kanban articles were altered in order to reflect the new system. An on going exercise started to re-route the other cell components identified during the

analysis. The already issued paperwork (orders in backlog) was altered and the new system was gradually initiated as the orders were released to the cell. The lead time achieved for the cell components was one week.

Despite the benefits achieved, the fabrication cell existed in isolation. The components produced by the cell constitute a fraction of the production at Reyrolle Switchgear Ltd. The performance of the manufacturing site can only be as good as the performance of the bottlenecks in the system. The problems encountered at the other areas of the factory such as the machine shop and heavy fabrication site, will cause delays and reduce the effectiveness of the fabrication cell. These remaining areas have to be analysed and new cells should be formed. Only then, the benefits of cellular manufacturing can be realised. The Production Flow analysis methodology provides a workable and effective guideline for the product based re-organisation of a manufacturing company.

The pull system that was already in place became more reliable and effective due to the performance of the fabrication cell. The Decision Support System, however, was not implemented due to the fact that the company decided (in July 1992) to proceed with the re-organisation of the manufacturing site. The re-organisation was based on the Production Flow analysis methodology. This change in the manufacturing strategy postponed the integration of the pull system until the new organisation evolved. The new system will comprise product dedicated cells that will supply the assembly lines of the products.

It should be noted, however, that the scope of the Decision Support System was enhanced even more. The simplification of the existing manufacturing system will reveal the repetitive (or non repetitive if this is the case) nature of components. The distribution of control will make the day to day activities more manageable, and planning more effective as the complexity will be reduced. It is expected that

the implementation of a Kanban system will become a *must* rather than a possibility and the number of components as well as the number of cells will increase. Under these circumstances the use of the Expert system will enhance the decision making of what is required, when, and where, providing the flexibility that is required.

Change in shop floor organisation should not be treated in isolation. Islands of excellence will not improve the performance of the company. Companies that go through change programs should consider a total re-organisation based on the product requirements. Their objectives should be to establish simple, and visible systems that every one understands and accepts. The role of CAPM systems is to support these activities. The more effective the organisation is, the more efficient the CAPM system will be. The effectiveness of an organisation can be increased when the people who constitute the system take ownership and responsibility of change, and day to day activities. Everyone from the top management to the operators have to be committed to the objectives of the change program. A prerequisite for the success of a manufacturing change program is the development of a bottom up initiative. This can only happen when the top management of the company releases power and authority to the lower levels, thus allowing people to get involved.

BIBLIOGRAPHY

Aggarwal, S. C. (1985), MRP, JIT, OPT, FMS? Making Sense of Production Operating Systems, *Harvard Business Review*, September-October.

Archer, G. BDO Consulting (1990), MRP: a review of failure and a proposal for recovery using CBS, *BPICS Control*, December/January, 27-31.

Bard, J. F. and Golany, B. (1991), Determining the number of kanban in a multiproduct multistage production, *International Journal for Production Research*, VOL 29, NO 5, 881-895.

Barekat, M. M. Stoy Hayward Consulting (1990), Distributed Manufacturing Resource Planning (DMRP) an alternative MRPII implementation strategy, *BPICS Control*, April/May.

Barker, R. C. (1991), Quality in the drive to World Class Manufacturing, *BPICS Control*, August/September, 29-31.

Berkley, B. J. (1991), Tandem queues and kanban-controlled lines, *International Journal for Production Research*, VOL 29, NO 10, 2057-2081.

Bichero, J., The Journey, *Productivity SA*, October, VOL 12, NO 5, 18-23.

Burbidge, J. L. Falster, P. and Riis, O. J. (1991), Why it is difficult to sell GT and JIT to industry?, *Production Planning and Control*, VOL 2, NO 2, 160-166.

Burbidge John L., (1978), The principles of Production Control, *Macdonald and Evans*.

- Burbidge John L., (1975), *The Introduction to Group Technology*, Heinemann London .
- Burbidge John L., (1989), *Production Flow Analysis for planning Group Technology*, Clarendon Press Oxford.
- Burcher, P. (1991), Closing the loop in Manufacturing Resource Planning Systems, *BPICS Control*, August/September, 35-39.
- Butcher, M. C. Perkins, N. R. Wells, K.E. and Peto, M. G. (1987), An advanced Intergrated Manufacturing System for turbin and compressor discs, *Proc Instn Mech Engrs*, VOL 201, NO 33.
- Byers, J. (1991), Controlling variety through a make VS buy policy for strategic products and components, *BPICS Control*, August/September, 41-42.
- Charniak, E. and McDermott, D. (1985), *An introduction to Artificial Intelligence*, Addison-Welsey Publishing CO.
- Cheng, T. C. E. (1991), Some thoughts on the practice of just-in time manufacturing, *Production Planning and Control*, VOL 2, NO 2, 167-178.
- Choobineh F. (1984), Optimum Loading for GT/MRP Manufacturing systems, *Computer and Industrial Engineering*, Vol 8, No 3/4, 197-206.
- Cooper,L. and Cooper, M (1981), *Introduction to Dynamic Programming*, Pergamon Press.

- Crosby, L. B. (1984), The Just-In Time manufacturing Process, *Production and Inventory Management*, Fourth Quarter, 21-33.
- Davidson, G., KANBAN in the Toyota Production System, *Productivity SA*, October, VOL 12, NO 5, 26-31.
- Dewhurst, F. W. and Gwinnett, E. A. (1990), Artificial Intelligence and Decision Analysis, *Artificial Intelligence in Operational Research*, Operational Research Society Ltd., 277-282.
- Diltes, D. M. Boyd, N. P. and Whorms, H. H., The evolution of control Architectures for automated Manufacturing System, *Journal of Manufacturing System*, VOL 10, NO 1.
- Docherty, J., Rowen Mobeni: A South Africa plant that has profited from the succesful implementation of JIT, *Productivity SA*, October, VOL 12, NO 5, 32-35.
- Doumengts, G., GRAI approach to designing and Controlling Advansed Manufacturing Systems in CIM environment, *NATO ASI Series*, VOL F53, 461-529.
- Dutta, A., Knowledge Based Approaches for production control: An Assessment, *NATO ASI Series*, VOL F53, 581-597.
- Edwards, J. (1990), Education for change, *BPICS Control*, October/November, 25-29.
- Feigendourn, A. V. (1986), Total Quality Control, *Mc Graw Hill*.

- Flapper, S. D. P. Miltenburg, G. J. and Wijngaard, J. (1991), Embedding JIT into MRP, *International Journal for Production Control*, VOL 29, NO 2, 329-341.
- Foddy, K. (1990), A slice of MRPII implementation, *BPICS Control*, October/November, 31-36.
- Galbraith, L. Miller, W. A. and Green, T. J. (1991), Pull system performance measures: a review of approaches for system design and control, *Production Planning and Control*, VOL 2, NO 1, 24-35.
- Galvin P.C. (1986), Visions and Realities: MRP as "System", *Production and Inventory Management*, Third Quarter, 91-95.
- Goldratt M. Eliyahu and Jeff Cox, (1986) *The Goal A Process of Ongoing Improvement*, North River Press, Inc.,.
- Golhar, D. Y. and Stamm, C. L. (1991), The Just in Time Philosophy: A literature review, *International Journal for Production Research*, VOL 29, NO 4, 657-676.
- Graham, L. A. (1991), A case study of a Japanese automobile plant, *Ph.D. thesis, Purdue University*.
- Guthrie, G. (1987), After Japan and beyond, *Production Engineer*, May, VOL 66, NO 6, 29-31.
- Hall, R. W. (1982), Kawasaki U.S.A., *APICS*, Virginia.

Hall, R. W., Driving the Productivity Machine, *APICS*, Virginia.

Hall, R. W., Implementation of Zero Inventories/Just in Time, *APICS*, Virginia.

Hall, R. W. (1987), Attaining the Manufacturing Excellence, *APICS*, Virginia.

Hall, R. W. (1983), Zero Inventories, *APICS*, Virginia.

Hegstad, M., A simple low risk approach to JIT, *Production and Control*, VOL 1, NO 1, 53-60.

Hodgson, T. J. and Wang, D. (1991), Optimal hybrid push/pull control strategies for a parallel multistage system: Part I, *International Journal for Production Research*, VOL 29, NO 6, 1279-1287.

Hodgson, T. J. and Wand, D. (1991), Optimal hybrid push/pull control strategies for a parallel multistage system: Part II, *International Journal for Production Research*, VOL 29, NO 7, 1453-1460.

Hodgson, A. (1987), Deming's never ending road to quality, *Personel Management*, 40-44.

Hutchins, D. (1990), Just in Time, *Gower Technical Press*.

Hutchins, J. Leong, K. Snyder, D. and Ward, P. (1991), Scheduling approaches for random job-shop flexible manufacturing systems, *International Journal for Production Rsearch*, VOL 29, NO 5, 1053-1067.

Japan Management Association (1985), Kanban and JIT at Toyota, *Productivity Press*.

Jewitt, R. (1990), Managing into the 90's: Just In Time an executive guide to JIT, *The Enterprise Initiative, DTI*.

Karkamar U. (1990), Getting Control of Just-In-Time, *Harvard Business Review The New Manufacturing*, 40-49.

Karmarkar, U.S. and Kerke, S. Eastman Kodak Company, Rochester New York, Batching in Kanban systems, *Journal of Manufacturing Systems*, VOL 8, NO 4.

Kochar, A. K., Computer Simulation of Manufacturing Systems -3 decades of Progress.

Lawrence, A. (1987), Do-It Yourself OPT, *Industrial Computing*.

Lawrence, N. (1990), Out of Africa, *BPICS Control*, October/November, 39-41.

Lawrence, A. (1987), MRP, OPT, JIT: The Facts, *Industrial Computing*, September, 17-21.

Lawrence, A. (1988), MRP, OPT, JIT: The Debate Continues, *Industrial Computing*, February, -64.

Lee, S. Y. and Chae, B.K., A study on MRP-based JIT system, *Proc. 3rd Int Conf. Just in Time Manufacturing*, 211-220.

- Li, A. and Co, H. C. (1991), A dynamic programming model for kanban assignement problem in a multistage multiperiod production system, *International Journal for Production Research*, VOL 29, NO 1, 1-16.
- Little, D. (1990), Survey of the UK Manufacturing control practice a brief report, *BPICS Control*, April/May, 31-33.
- Lockyer, L. Muhlemann, A. and Oakland, J (1988), *Production and Operations Management*. Pitman, Fifth Edition.
- Love, D. and Barekat, M. (1989), Decentralized, Distributed MRP: Solving control problems in Cellular Manufacturing, *Production and Inventory Management*, Third Quarter, 78-83.
- Love, D. M. Barton, J. A. and Cope N, (1992), Whole Business Simulation and Engineering Applications, *International Conference of Computer-Aided Production EGINEERING*, Edindurgh, August.
- Love , D.M. Sawyer, J.H.F. and Lung W.M., (1986), Distributed Planning and Control in a Cellular CIM system, *International Conference Series on Advances in Engineering Management Theory and Application*, 15th-19th September.
- Love, D.M. and Love A.L., Computerised component coding and the design of Cellular Manufacturing Systems, *3rd International Conference on Computer-Aided Production Engineering*, University of Michigan, Ann Arbor, Michigan, June 1-3 1988.
- Love D.M., The Design of Manufacturing Systems, *Aston University (notes)*.

- Love D.M., Manufacturing Control Systems, *Aston University (notes)*.
- Love Doug, (1992) Concepts, Implementation and Potential of DMRP, *IEE Seminar on DMRP and Cellular Manufacture, Savoy Place London, June 4*.
- Mallin, S. J. and Riddle, R. (1990), A new approach to stock management for fast and effective results, *BPICS Control*, December/January, 37-41.
- Malpas, R., Strategies for success in Manufacturing, *Proc Instn Mech Engrs*, VOL 201, NO 33.
- Managing into the 90's: Optimised Production Technology (1990), *The enterprise Initiative, DTI*.
- Marcellus, D. H., Expert Systems Programming in Turbo Prolog, Prentice Hall.
- Maruchek, A. S. and McChlellang, M. K. (1986), Strategic Issues in Make to Order Manufacturing, *Production and Inventory Management*, Second Quarter, 82-95.
- Mather, H. (1988), Competitive Manufacturing, *Prentice Hall Inc.*.
- Miltenburg, J. and Wijngaard, J. (1991), Designing and phasing in just-in-time production systems, *International Journal for Production Research*, VOL 29, NO 1, 115-131.
- Nellemann, D. O. Arthur Anderson & Co, Tokyo Japan (1982), "Just in time" VS Just in case production/inventory systems, concepts borrowed back from Japan, *Production and Inventory Management*, Second Quarter.

- Nemhauser, G.L. and Rinnooy, K. and Todd, M. J. (1989), *Optimisation, North Holland.*
- Niehaus, T. L., The Courtship of JIT and MRP: A case study.
- Norrie, D. H. Fauvel, O. R. and Gaines, B. R. (1990), Object Oriented management planning systems for advanced manufacturing, *INT J Computer Integrated Manufacturing*, VOL 3, NO 6, 373-378.
- Oliver, N. and Wilkinson, B. (1988), The Japanization of British Industry, *Basil Blackwell.*
- Parnaby, J. (1979), Concept of a manufacturing system, *International Journal of Production Research*, VOL 17, NO 2.
- Parsons, D. Dun & Bradstreet Software (1991), The principles of Distribution Resource Planning (DRP) closing the MRPII loop, *BPICS Control*, April/May, 23-25.
- Parunak, H. V., Characterizing the Manufacturing Problem, *Journal of Manufacturing Systems*, VOL 10, NO 3, 241-259.
- Paul, R. J. and Doukidis, G. I (1992), Operational Research Approaches to Artificial Intelligence in Production Planning and Scheduling, *Artificial Intelligence in Operational Research*, *Operational Research Society Ltd.*, 135-138.

- Penlesky, R. J. Wemmerlov, U. and Berry, N. (1991), Filtering heuristics for rescheduling open orders in MRP systems, *International Journal for Production Research*, VOL 29, NO 11, 2279-2296.
- Peyronnet, F., Improving workflow in the shop: MRP/KANBAN integration.
- Plenert, G. and Young, B., Bottleneck scheduling for an unlimited number of products, *Journal of Manufacturing Systems*, VOL 9, NO 4, 324-330.
- Pluym, D. V. D. (1990), Knowledge-based decision making for job shop scheduling, *International Journal for Computer Integrated Manufacturing*, VOL 3, NO 6, 354-363.
- Price Waterhouse Management Consultants UK (1987), JIT -small batch production, *Proc 4th European Conf Automated Manufacturing*, 193-212.
- Prickett, P. and Coleman, J (1992), The Implementation of a Cell-Based Manufacturing System, *International Journal of Advanced Manufacturing Technology*, Vol 7, 203-209.
- Prickett P. (1992), The implementation of a Cell based Manufacturing System, *International Journal of Advances in Manufacturing Technology*, Vol 7, Part 4, pp 203-209.
- Primose, P. L. (1990), The economics of MRPII, *BPICS Control*, October/November, 44-46.
- Primose, P. L. (1990), MRPII: A case study, *BPICS Control*, April/May, 35-36.

- Riehl, K. G. and Kleiner, B. H. (1987), Lessons from the Japanese Automotive Industry, *Industrial Management and Data Systems*, May/June, 3-6.
- Riggs, J. L. (1987), Production Systems: Planning, analysis and control, *John Wiley & Sons Inc.*, Fourth Edition.
- Ryzin, G. J. V. Lou, S. X. C. and Gershwin, S. T. B. (1991), Scheduling job shop with delays, *International Journal for Production Research*, VOL 29, NO 7, 1407-1422.
- Sandras, B. (1984), About Face Materials, *Productivity SA*, October, VOL 12, NO 5, 6-12, 14-23, 26-35.
- Savage, W. G. William Savage & Associates Inc., Systems Implementation with MRPII and JIT concepts.
- Schonberger, R. J. (1982), Japanese Manufacturing Techniques, Nine Hidden Lessons in Simplicity, *The Free Press*.
- Schonberger, R. J. (1984), Just in Time Production System: Replacing complexity with Simplicity in Manufacturing Management, *IE*, October, 52-64.
- Shah, S. Buthcer, P. and Geoffrey Relph IBM UK Ltd (1990), Extending the Pareto Principle to MRP controlled parts and regaining MRP control, *BPICS Control*, April/May.
- Shingo, S. (1986), Zero Quality Control: Source inspection and the Poka Yoke System, *Productivity Press*.

- Shingo, S. (1989), Study of the Toyota Production systems, *Productivity Press*.
- Shingo, S. (1985), A revolution in Manufacturing: The SMED system, *Productivity press*.
- Silver, E. A. and Peterson, R. (1985), Decision Systems for Inventory Management and Production Planning, *John Wiley & Sons*.
- Smith, S. and Tranfield, D. (1989), A catalytic implementation methodology for CIM, *INT J Computer Intergrated Manufacturing*, VOL 12 NO 3, 140-147.
- Smith, S. Tranfield, D. Ley, C. Bessant, J. and Lery, P., A new paradigm for the organisation of manufacturing, *Integrated Manufacturing Systems*, VOL 2, NO 2, 14-21.
- Solberg, J. J. and Hein, J. A., Managing Information complexity in material flow systems, *NATO ASI Series*, VOL F53, 3-19.
- Swale, R. (1990), MRPII implementation: Why it is do painful, *BPICS Control*, October/November, 35-38.
- Swann, D. Haskins, D. and Shells Atlanda GA (1986), Using MRP for optimised schedules (emulating OPT), *Production and Inventory Management*, Second Quarter.
- Villa, A., Information Processing in material flow system management, *NATO ASI Series*, VOL F53, 601-635.

Vollmann, T. (1986), OPT and enhancement to MRPII, *Production and Inventory Management*, Second Quarter, 38-47.

Vollmann, T. E. Berry, W. L. and Whybark, D. C. (1988), *Manufacturing Planning and Control Systems*, Dow Jones Irwin, Second Edition.

Voss, C. A. and Harrison, A., *JIT in the Manufacturing Strategy*, University of Warwick.

Voss, C. A. (1988), *Just in Time Manufacture*, IFS (Publications) Ltd., UK, Springer Verlag.

Voss C. A., JIT's Here to stay, Managing for success, *Proceedings, of the 4th international Conference on Just in time manufacturing*, 17-18 October 1989, London UK.

Walters, H. and Shtakleff, R. (1990), From OR to Knowledge-based Systems: An Industrial Experience, *Artificial Intelligence in Operational Research*, Operational Research Society Ltd., 23-29.

Weber, D. M. and Moodie, C.L., Distributed, Intelligent Information system for automated intergrated manufacturing systems, *NATO ASI Series*, VOL F53, 57-79.

Wells A. J. (1989), Cellular Facility Design Made easy, *IFAC Information Control Problems in Manufacturing Technology*, Madrid Spain, 341-345.

White, M. K., Intergrating JIT with our existing systems - an Australian case study at S.T.C.

Wiener Nobert, (1949), *Cybernetics, The technology Press* .

Wild, R. (1989), *Production and Operations Management, Cassel*.

Williams H. P. (1985), *Model Building in Mathematical Programming, John Wiley & Sons*.

Winston, P. H. (1984), *Artificial Intelligence, Addison-Welsey Publishing CO*.

Young, R., *CIM System Development for small to medium size discrete-parts Manufacturing companies, NATO ASI Series, VOL F53, 637-650*.

APPENDICES



APPENDIX I

Figure A1. The LMT Switchgear.

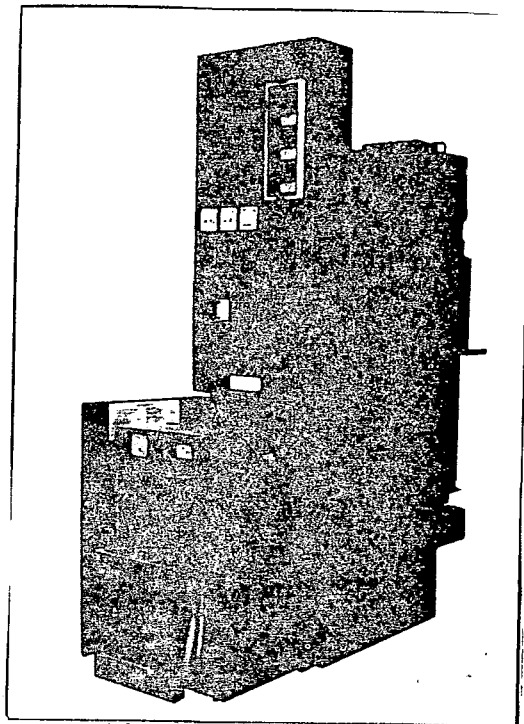


Figure A2. The LSR Switchgear.



Figure A3. The YMV Switchgear.



Figure A4. The SMS Switchgear.

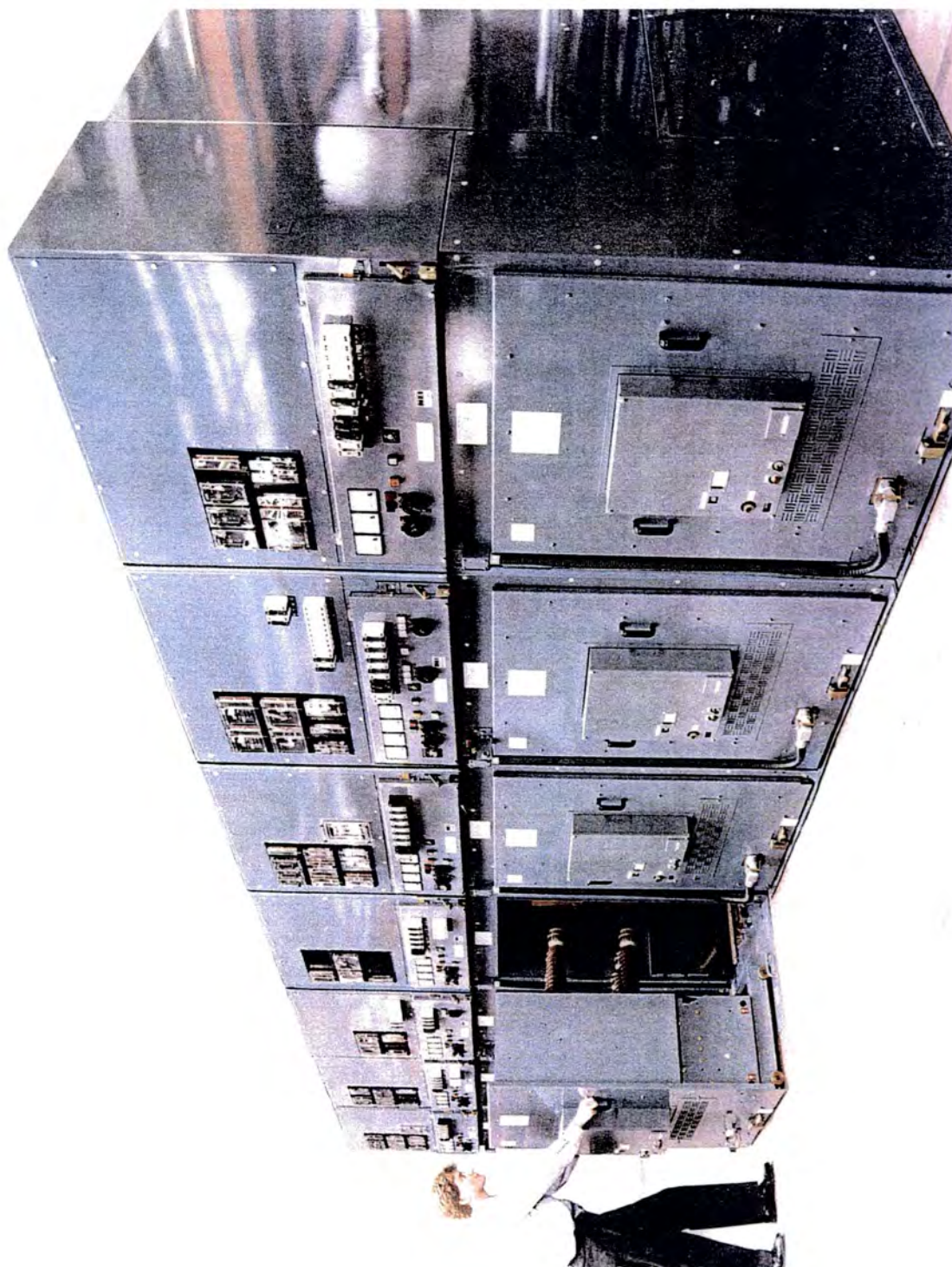


Figure A5. The RO Switchgear.

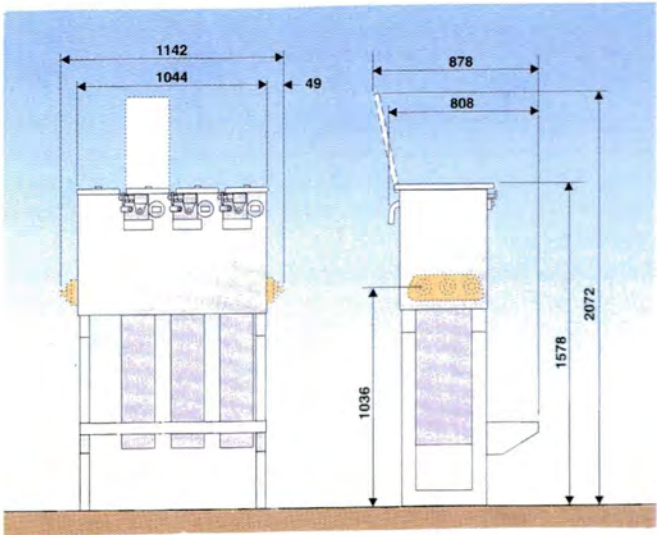
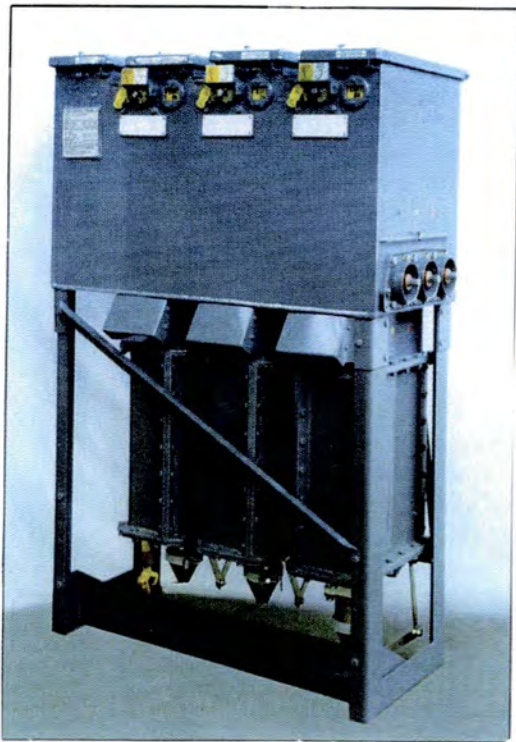


Figure A6. The ESR Switchgear.

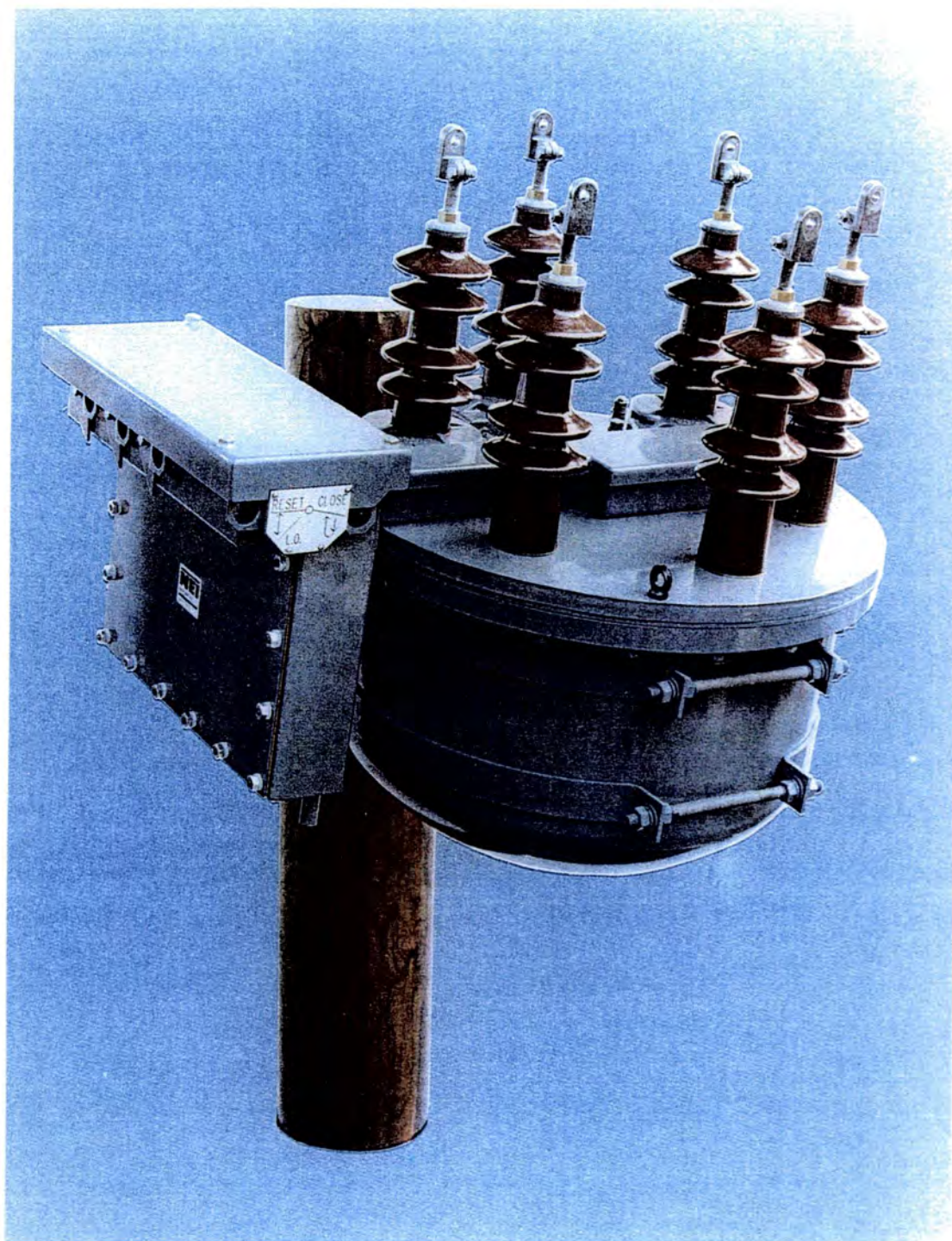


Figure A7. The GIS (HV) Switchgear.

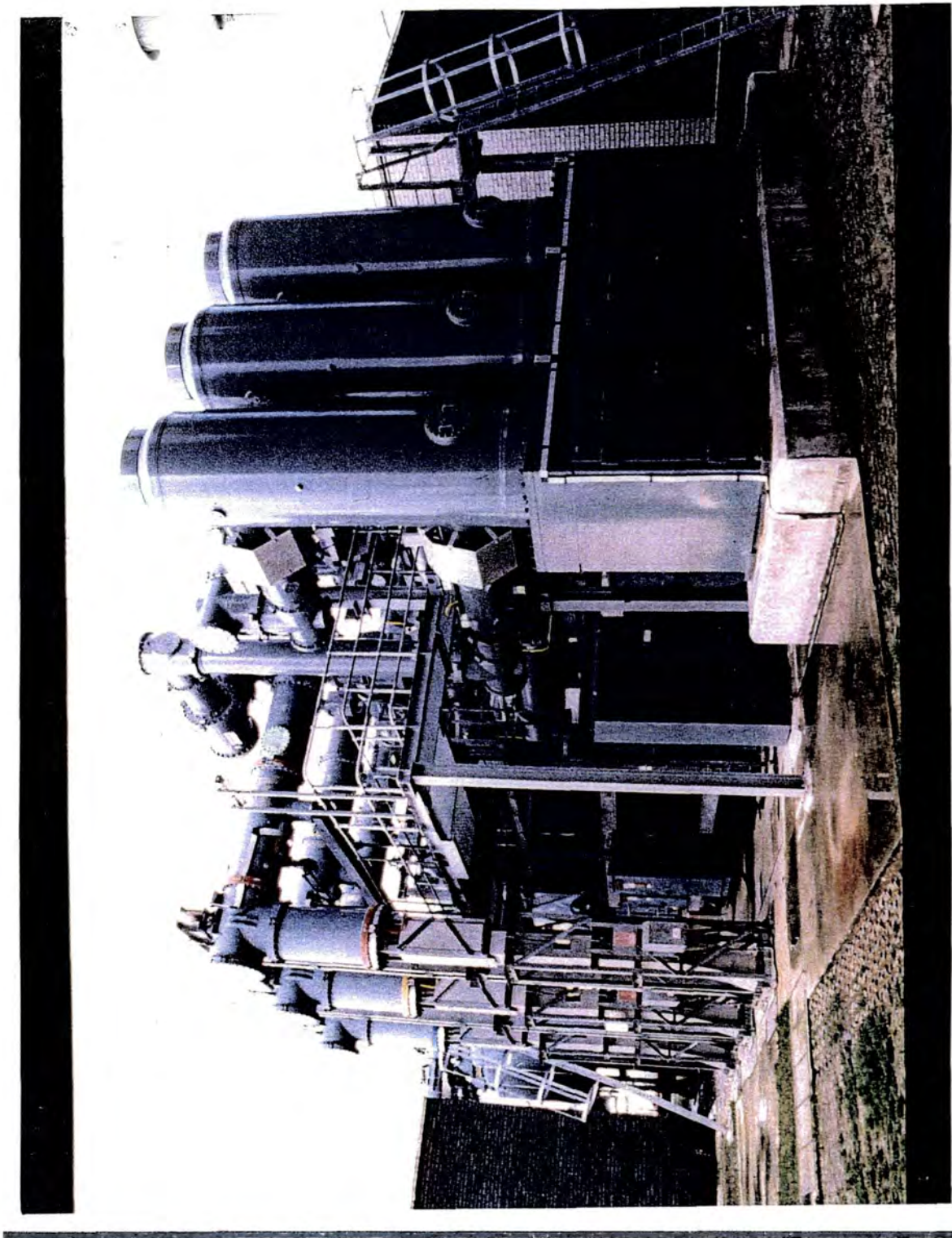


Figure A8. The assembly Shop at Reyrolle Switchgear Ltd.



Figure A9. The fabrication shop at Reyrolle Switchgear Ltd.



Figure A10. An example of a single explosion of the bill of materials for the nested article 974A1495N.

BLLSLX (BLLSLX) BOM		SINGLE LEVEL BOM DISPLAY		(001,REV) 21/12/92(239)	
974A1495N		;21/12/92; ;G		PAGE 1 MORE	
PART NBR: 974A1495N		RLSE STAT: PROD		CUR MFG REV:	
DESC: CRUDE FRAMEWORK KIT		MFD TYPE: M		BOM UOM: EACH LATEST ENG REV:	
DATE: 21/12/92 REV:		VIEW: G			

SEQ NBR/	COMPONENT PART NBR/	BOM	V Q	QTY PER/	-----BEGIN/END----- E
REFERENCE	TY DESCRIPTION	UOM	W T	SHRK FCTR -DATE--	---ECN--- REV C
00010	1153-30130T	KG	G 1	162.000 29/04/92	AAA-002819
	P MS SHEET 2MM THK		BO	0.000	*****
00020	974X1493	EACH	G 1	1.000	*****
	M SIDESHEET L.H. W.S.			0.000	*****
00030	974X1480	EACH	G 1	1.000	*****
	M SIDESHEET RH WS			0.000	*****
00040	974X4	EACH	G 1	1.000	*****
	M ANGLE			0.000	*****
00050	974X1515	EACH	G 1	1.000	*****
	M BLANKING COVER			0.000	*****
00060	974X6	EACH	G 1	1.000	*****
	M ANGLE			0.000	*****

BLLSLX (BLLSLX) BOM		SINGLE LEVEL BOM DISPLAY		(001,REV) 21/12/92(239)	
974A1495N		;21/12/92; ;G		PAGE 2 LAST	
PART NBR: 974A1495N		RLSE STAT: PROD		CUR MFG REV:	
DESC: CRUDE FRAMEWORK KIT		MFD TYPE: M		BOM UOM: EACH LATEST ENG REV:	
DATE: 21/12/92 REV:		VIEW: G			

SEQ NBR/	COMPONENT PART NBR/	BOM	V Q	QTY PER/	-----BEGIN/END----- E
REFERENCE	TY DESCRIPTION	UOM	W T	SHRK FCTR -DATE--	---ECN--- REV C
00070	974X7	EACH	G 1	1.000	*****
	M ANGLE			0.000	*****
00080	974X891	EACH	G 1	1.000	*****
	M SUPPORT PLATE			0.000	*****
00090	974X9	EACH	G 1	1.000	*****
	M SUPPORT PLATE			0.000	*****
00100	974X136	EACH	G 1	1.000	*****
	M BARRIER			0.000	*****
00110	974X12	EACH	G 1	1.000	*****
	M ANGLE			0.000	*****
00120	974X14Y	EACH	G 1	1.000	*****
	M REAR COVER			0.000	*****

Figure A11. An example of a multi explosion of the bill of materials for the nested article 974A1495N.

BLLMLX (BLLMLX) BOM INDENTED EXPLOSION DISPLAY (001,REY) 21/12/92(239)
974A1495N 21/12/92; ;G PAGE 1 MORE

PART NBR: 974A1495N RLSE STAT: PROD CUR MFG REV:
DESC: CRUDE FRAMEWORK KIT MFD TYPE: M BOM UOM: EACH LATEST ENG REV:
DATE: 21/12/92 REV: VIEW: G

LEVEL	SEQ	NBR/	COMPONENT	PART NBR/	BOM	V	Q	QTY	PER/	--BEGIN/END--	EF
NUMBER	REFERENCE	TY	DESCRIPTION		UOM	W	T	SHRK	FCTR	--DATE-- REV	CD
.1	00010		1153-30130T		KG	G	1	162.000		29/04/92	
		P	MS SHEET 2MM THK		BO			0.000		*****	
.1	00020		974X1493		EACH	G	1	1.000		*****	
		M	SIDESHEET L.H. W.S.					0.000		*****	
..2	00010		974X1483		EACH	G	1	1.000		*****	
		M	SIDESHEET M.S.					0.000		*****	
...3	00010		974X1484		EACH	G	1	1.000		*****	
		M	SIDESHEET BLANK					0.000		*****	
....4	00020		EWN6017		EACH	G	1	1.000		*****	
		M	WORKS NOTE					0.000		*****	
..2	00020		974X1482		EACH	G	1	1.000		*****	
		M	ANGLE					0.000		*****	

BLLMLX (BLLMLX) BOM INDENTED EXPLOSION DISPLAY (001,REY) 21/12/92(239)
974A1495N 21/12/92; ;G PAGE 2 MORE

PART NBR: 974A1495N RLSE STAT: PROD CUR MFG REV:
DESC: CRUDE FRAMEWORK KIT MFD TYPE: M BOM UOM: EACH LATEST ENG REV:
DATE: 21/12/92 REV: VIEW: G

LEVEL	SEQ	NBR/	COMPONENT	PART NBR/	BOM	V	Q	QTY	PER/	--BEGIN/END--	EF
NUMBER	REFERENCE	TY	DESCRIPTION		UOM	W	T	SHRK	FCTR	--DATE-- REV	CD
...3	00020		EWN6016		EACH	G	1	1.000		*****	
		M	WORKS NOTE					0.000		*****	
..2	00030		974X1477		EACH	G	1	1.000		*****	
		M	ANGLE					0.000		*****	
...3	00020		EWN6014		EACH	G	1	1.000		*****	
		M	WORKS NOTE					0.000		*****	
..2	00040		974X1475		EACH	G	1	1.000		*****	
		M	SUPPORT BRACKET					0.000		*****	
...3	00020		EWN6012		EACH	G	1	1.000		*****	
		M	WORKS NOTE					0.000		*****	
..2	00050		974X1347		EACH	G	1	1.000		*****	
		M	SUPPORT					0.000		*****	

Figure A13. An example of the details that the system holds for the operations for the nested article 974A1495N.

```
OPNDTL (OPNDTL) BOM PRODUCTION ROUTING DETAIL DISPLAY (001,REY) 21/12/92(239)
974A1495N PAGE 3 MORE

PART NBR: 974A1495N DESC: CRUDE FRAMEWORK KIT MFD PL ID: C05N

RSRC BEGN END
SEQ CNTRL CD DATE DATE WCTR OP S/U PL
ID DESCRIPTION ID CL CL OP
0020 0 00 HR ***** TEXT FLOEL E N
-----OPERATION-----
-----RESOURCE REQUIREMENT----- --OVERLAP-- ---MACHINE--- --TIMES-- --RATES--
SETUP U/M CONV FCTR RUN QTY/PCT ID QUE MOV SD RUN BD
0.00 HR 1.0000 2.0335 0/100 *** * * *
SHRINK FCTR: 0.000 LOT FCTR: 0.000 REWORK: N COST IND: Y MILESTONE: *

FIXED TOOL COST: 0.00000 VARIABLE TOOL COST: 0.00000
-----
0020-7-00 HR ***** TEXT PUNCH. IC3 FLNC2 S N
0030-0-00 HR ***** BOOK TO STORES STORE * N
0060-7-00 HR ***** TEXT SEPARATE ARTS. FLSMI S N
```

Figure A14. An MRP record for the nested component 974A1495N.

```
MTLSUM (MTLSUM) MRP MATERIAL PLAN SUMMARY DISPLAY (001,REV) 21/12/92(239)
974A1495N PAGE 1 MORE
PART NBR: 974A1495N DESC: CRUDE FRAMEWORK KIT MFD PL ID: COSN
STOCK ON HAND: 0 STOCK ALLOCATED: 61 SAFETY STOCK: 0

PERIOD/SHOP DT OVERDUE 01(W)-239 02(W)-001 03(W)-006 04(W)-011 05(W)-016
CALENDAR DATE ***** 21/12/92 04/01/93 11/01/93 18/01/93 25/01/93
PROJ ON HAND 0 7 0 5 0 7
OPEN ORDERS 30 0 0 0 0 0
PLND ORDERS 20 0 0 0 0 0
PLND AVAIL 50 7 37 20 20 7
DEMAND 43 0 32 13 13 4
END BALANCE 7 7 5 7 3 3

PERIOD/SHOP DT 06(W)-021 07(W)-026 08(W)-031 09(W)-036 10(W)-041 11(W)-046
CALENDAR DATE 01/02/93 08/02/93 15/02/93 22/02/93 01/03/93 08/03/93
PROJ ON HAND 3 3 9 7 7 4
OPEN ORDERS 0 0 0 0 0 0
PLND ORDERS 10 10 20 0 10 10
PLND AVAIL 13 13 29 7 17 14
DEMAND 10 4 22 0 13 13
END BALANCE 3 9 7 7 4 1
>MTLDTL
```

Figure A15. The MPS information for the nested component 974A1495N.

```

MPSUM (MPSUM) MPS          (001,REV) 21/12/92(239)
974A1495N                  PAGE 1 MORE

PART NBR: 974A1495N        DESC: CRUDE FRAMEWORK KIT   MFD PL ID: C05N
TYPE: M

-----STOCK-----
ON HAND 0    SAFETY 0    ALLOC 61    YEAR TO DATE FIELDS-----
                                PROD FCST  SERV FCST  DEMAND  PROD/RECPT
                                0          0          0          0

STANDARD PLANNING DEMAND ---FENCES---
PRD SIZE HORIZON  LT  RR  FP  CD QUANTITY PRD  MINIMUM  MAXIMUM SHRK
W-WEEK   ***(W)  ***(W)  9  12  12  12  FG  10  5  0  0  0  0.000

PERIOD  CALENDAR DAY  OVERDUE  01(F)  02(F)  03(F)  04(F)  05(F)
*****  04/01/93  01/02/93  01/03/93  29/03/93  26/04/93
PROD FCST  0  0  0  0  14  7  11
SERV FCST  0  0  0  0  0  0  0
DEMAND    43  36  33  49  5  22
AVAILABLE  7  7  4  5  1  3
AVAIL TO PROM  0  4  -3  1  -2
MPS ORDERS  50  40  30  50  20

                                >MTLOUT

```

Figure A16. An example of a dispatch list for the workcentre FLNC1.

SFCWTL (SFCWTL) SFC SHOP FLOOR WORK TO LIST (001,REV) 21/12/92(239)
FLNC1 PAGE 1 MORE

DISPATCH HORIZON: 05/01/93(002)
WORK CTR: FLNC1 DESC: CNC PUNCHING T180W DEPT: 0241 PL ID: PC

PART NUMBER/ DESCRIPTION	ORD ID/ CNTRL ID	ORD QTY/ LOCATION	ORD ST	ORD OP ST/ QTY	SEQ NBR/ OP DUE	OP STRT/ OP DUE	PRV WC NXT WC	SU CL
874K990	090901-001	1	OP	0020-0-00	07/03/88	FLLG1		
PANEL CUT-OUT.		FLNC1	WK	1	07/03/88	FLPB1		
874K989	090910-001	1	OP	0030-0-00	07/03/88	FLLG1		
PANEL CUT-OUT			NA	0	07/03/88	FLPB1		
874K992	090999-001	1	OP	0020-0-00	07/03/88	FLLG1		
PANEL CUT-OUT			NA	0	07/03/88	FLPB1		
815A475	54093A-001	104	OP	0020-0-00	18/03/88	FLLG1		
CLAMP PLATE ELECTROMAGNET		FLNC1	WK	104	23/03/88	FLSM1		
815A475	45580Y-001	52	OP	0020-0-00	22/03/88	FLLG1		
CLAMP PLATE ELECTROMAGNET			NA	0	23/03/88	FLSM1		
814A189	105357-001	15	OP	0020-0-00	09/07/90	FLLG1		
BACK PLATE			NA	0	09/07/90	FLPB1		

SFCWTL (SFCWTL) SFC SHOP FLOOR WORK TO LIST (001,REV) 21/12/92(239)
FLNC1 PAGE 2 MORE

DISPATCH HORIZON: 05/01/93(002)
WORK CTR: FLNC1 DESC: CNC PUNCHING T180W DEPT: 0241 PL ID: PC

PART NUMBER/ DESCRIPTION	ORD ID/ CNTRL ID	ORD QTY/ LOCATION	ORD ST	ORD OP ST/ QTY	SEQ NBR/ OP DUE	OP STRT/ OP DUE	PRV WC NXT WC	SU CL
814A605	089702-001	9	OP	0020-0-00	02/08/90	FHGL1		
BRKT UPPER TERM.BOX. (1)			NA	0	02/08/90	FLRD1		
785A665F	056056-001	1	OP	0020-0-00	09/12/91	FLLG1		
SHROUD FOR AUX.SW.DRIVE		FLNC1	OH	1	10/12/91	FLPB1		
981A267X	73555A-001	12	OP	0010-0-00	06/02/92			
FRONT PLATE FOR TANK		FLNC1	AV	12	06/02/92	FIZ1Q		
981A267X	80720Z-001	9	OP	0010-0-00	06/02/92			
FRONT PLATE FOR TANK		FLNC1	AV	9	06/02/92	FIZ1Q		
981A267X	92044A-001	19	OP	0010-0-00	06/02/92			
FRONT PLATE FOR TANK		FLNC1	AV	19	06/02/92	FIZ1Q		
747A2871	58258S-001	21	OP	0010-0-00	13/03/92			
COVER - YGII EARTH SWITCH			AV	21	13/03/92	FHPF1		

Figure A17. Monitoring screen the status of open orders on the shop floor for a specific article.

```
SFCPRT (SFCPRT) TAR      SHOP FLOOR CONTROL DISPLAY  (001,REV)  21/12/92(239)
974A1495N                                     PAGE 1  LAST

974A1495N      CRUDE FRAMEWORK KIT      MFD      PLID: C05N
-----
ORD NBR  ORD QTY  CUR OP  ST  REC DAT  SIRT DAT  W/C  CUR QTY  O/S  RUN  NXT  W/C
-----
15433Y-001      10  0160  NA      14/12/92  16/12/92  FPPC1      10      F1Z5X
062696-001      10  0020  WK      FLCEL      10      20.34  STURE
REW100-401      1  0031  NA      STORE      1
062697-001      10  0020  NA      FLCEL      10      20.34  STURE
```

5.



Figure A19. The form of the paperwork issued for the operation within the FLCEL for the nested article 974A1514N

ROLST160

MANUFACTURING ORDER

PRINTED 25/09/92

ORDER 120340001

CONTROL ID.

QUANTITY : 10

GEAR DESC : LMT FROM FAB.

PC

GEAR CODE 1381

DRAWING - NO MDR

DESC

INCLUDED

BOOK TO

LMTD -B3-4

PART NUMBER 1974A1514N

DESC

INCLUDED

BOOK TO

LMTD -B3-4

0010 0 00

SEND TO START DEPT.

0020 0 00

FLCEL

MAKE (KIT)

PUNCH CPT. IC3 P3577

974X11 REV.4 974X5 REV.2

JOCGLE. IC3

974X5 REV.2

FIXTURE

974T5/2

BEND. IC3

974X5 REV.2

FIXTURE

974T5/3

FINISH 31/C/418 IC3

974X5 REV.2 974X11 REV.4

FLCEL

FLPBI

FLPBI

0030 0 00

BOOK TO STORES

0030 0 00

18

STORE

ENSTR

SET

RUN

ROLST160

MANUFACTURING ORDER

PRINTED 25/09/92

ORDER 120340001

CONTROL ID.

QUANTITY : 10

GEAR DESC : LMT FROM FAB.

PC

GEAR CODE 1381

DRAWING - NO MDR

DESC

INCLUDED

BOOK TO

LMTD -B3-4

PART NUMBER 1974A1514N

DESC

INCLUDED

BOOK TO

LMTD -B3-4

0010 0 00

SEND TO START DEPT.

0020 0 00

FLCEL

MAKE (KIT)

PUNCH CPT. IC3 P3577

974X11 REV.4 974X5 REV.2

JOCGLE. IC3

974X5 REV.2

FIXTURE

974T5/2

BEND. IC3

974X5 REV.2

FIXTURE

974T5/3

FINISH 31/C/418 IC3

974X5 REV.2 974X11 REV.4

FLCEL

FLPBI

FLPBI

0030 0 00

BOOK TO STORES

0030 0 00

18


STORE


ENSTR

SET





RUN

Figure A20. The form of the paperwork issued before the FLCEL was created for the nested article 974A1514N.

REYSFC006	MANUFACTURING ORDER	PRINTED 20/12/92
		
ORDER 099651001		
CONTROL ID.		QUANTITY : 4

GEAR DESC : RO FROM FAB	PC	GEAR CODE : 490
		
DRAWING - NO	PART NUMBER : 981A469	
- SIZE -2S	DESC : BACKPLATE FOR TANK	
- REV.	INCLUDED :	
	BOOK TO : QW3 -FLR	

MATERIAL SHEET
ATTACHED

	SET	RUN
0010 0 00 FLSW1 S.WELD	0.2900	0.0250
ASSEMBLE & SPOT WELD	BRACKETS.981T471/1-/2	
IC3		
.....		
	SET	RUN
0020 0 00 FLSW2 STUD W		
ASSEMBLE & WELD STUDS	981T467/2	
IC3		
.....		
	SET	RUN
0030 0 00 FERD1 H.RAD	0.2700	0.0250
REMOVE FLASH		
IC3		
.....		
	SET	RUN
0050 0 00 IH PSREC		
BOOK TO STORE		
.....		

APPENDIX II.

INSTALLATION THE DECISION SUPPORT SYSTEM

In order for the system to work Crystal 4.5 should be already installed on the hard disc and there must be at least 2Mb RUM available on the computer. Insert the floppy disc in the appropriate drive. From the DOS "C:\>" prompt move into the directory "CRYSTAL4" using the command "cd Crystal4". Copy all the files from the floppy diskette into the directory on the hard disc.

To run the system from the "C:\CRYSTAL4\>" prompt type 'DSS', and the main menu will appear on the screen.

APPENDIX III.

THE SOURCE CODE FOR THE DECISION SUPPORT SYSTEM.

```
[ 143] START THE SYSTEM                                Sp

      IF      DO: Test Expression

          MAINMEN=1

+ AND [ 66] DISPLAY THE CURRENT JOBS

      OR      DO: Test Expression

          MAINMEN=2

+ AND [ 145] START UPDATING THE INV REQ AND DSS

      OR      DO: Test Expression

          MAINMEN=3

+ AND [ 43] CLOSE THE ORDERS IN DSS

      OR      DO: Test Expression

          MAINMEN=4

+ AND [ 125] OPEN REQ AND GET DATA

      OR      DO: Test Expression

          MAINMEN=5

+ AND [ 164] unexpected inv replenishment

      OR      DO: Test Expression
```

MAINMEN=6

+ AND [170] update the assembly orders

OR DO: Test Expression

MANIMEN=7

AND DO: Quit

[66] DISPLAY THE CURRENT JOBS Sp

+ IF [112] Initialise

+ AND [67] display the requirements

[112] Initialise Sp

+ IF [142] Set fixed values

+ AND [31] Check interface is loaded

+ AND [44] Closedown

F AND DO: Help Explain

*

+ AND [124] Open file

+ AND [138] Select database file1

+ AND [103] Goto first

AND DO: Assign Variable

nof:=DBgetflds(a\$[#],b\$[#],c[#],d[#])

+ AND [39] Clear out fields

+ AND [130] Read data

+ OR [179] Wipe

AND DO: Restart Rule

[142] Set fixed values Sp

IF DO: Init. Variables

AND DO: Assign Variable

DBF\$:=" "

+ AND [154] Test seperator

+ AND [94] Get default date format

[154] Test seperator Sp

IF DO: Test Expression

getsep()=0

AND DO: Assign Variable

s\$:="-"

OR DO: Test Expression

getsep()=1

AND DO: Assign Variable

s\$:="/"

OR DO: Test Expression

getsep()=2

AND DO: Assign Variable

s\$:= "."

[94] Get default date format Sp

IF DO: Test Expression

getform()=0

AND DO: Assign Variable

df\$:="DD"+s\$+"MM"+s\$+"YYYY"

*

OR DO: Test Expression

getform()=1

AND DO: Assign Variable

df\$:="MM"+s\$+"DD"+s\$+"YYYY"

OR DO: Test Expression

getform()=2

AND DO: Assign Variable

df\$:="YYYY"+s\$+"MM"+s\$+"DD"

[31] Check interface is loaded Sp

+ IF [38] Clear error flag

AND DO: Test Expression

verify("dbcr")

+ AND [27] Check for error

F OR DO: Display Form

AND DO: Quit

[38] Clear error flag Sp

IF DO: Test Expression
errclr()

[27] Check for error Sp

IF DO: Test Expression
errok()

Closedown Sp

+ IF [38] Clear error flag
AND DO: Test Expression
DBcloseall()

+ AND [27] Check for error

[124] Open file Sp

IF DO: Assign Variable
drfh:=DBopen("a:\dsss")
AND DO: Assign Variable
drfh1:=DBopen("a:\INV")
AND DO: Assign Variable
drfh2:=DBopen("a:\req")

Sp

Sp

Sp

Sp

Sp

Sp

[130] Read data Sp

+ IF [115] Load all fields
+ AND [150] Test for delete mark
AND DO: Assign Variable
recsub:=0
+ AND [54] Convert to text
AND DO: Fail

OR DO: Succeed

[115] Load all fields Sp Ex

IF DO: Test Expression
erron()
AND DO: Test Expression
DBreadrec(dt[#])
AND DO: Test Expression
DBreadrec(dt\$[#])
AND DO: Assign Variable
recsub:=0

[150] Test for delete mark Sp

+ IF [162] Turn off errors
+ AND [62] Delete record
AND DO: Assign Variable

```

recdel:=0

+ AND [ 133] Recall record

OR      DO: Assign Variable

recdel:=1

[ 162] Turn off errors                               Sp

IF      DO: Test Expression

erroff()

[ 62] Delete record                               Sp

+ IF [ 38] Clear error flag

AND      DO: Test Expression

DBdelete(DBrecno())

+ AND [ 27] Check for error

[ 133] Recall record                               Sp

+ IF [ 38] Clear error flag

AND      DO: Test Expression

DBrecall(DBrecno())

+ AND [ 27] Check for error

/

[ 54] Convert to text                               Sp

IF      DO: Assign Variable

cnt:=0

```

+ AND [47] Convert loop

[47] Convert loop

Sp

IF DO: Test Expression

b\$[cnt]="N"

AND DO: Assign Variable

dt\$[cnt]:=string\$(dt[cnt],c[cnt],d[cnt])

AND DO: Fail

OR DO: Test Expression

b\$[cnt]="L"

AND DO: Assign Variable

dt\$[cnt]:=query\$(dt[cnt],"T","F")

AND DO: Assign Variable

dt[cnt]:=0

AND DO: Fail

OR DO: Test Expression

b\$[cnt]="D"

AND DO: Assign Variable

dt\$[cnt]:=date\$(dt[cnt])

AND DO: Assign Variable

dt[cnt]:=0

AND DO: Fail

```

OR      DO: Assign Variable
        cnt:=cnt+1

AND     DO: Test Expression
        cnt<nof

AND     DO: Restart Rule

OR      DO: Succeed

[ 179] Wipe                                     Sp
+ IF    DO: Wipe Rule
        Set fixed values

AND     DO: Wipe Rule
        Ask for filename

[ 67] display the requirements                 Sp
+ IF    [ 103] Goto first
+ AND [ 78] find the day's orders

[ 78] find the day's orders                     Sp
IF      DO: Assign Variable
        today:=now()

AND     DO: Assign Variable
        i:=0

+ AND [ 83] find the record

AND     DO: Test Expression
        i<0

[ 83] find the record                           Sp

```

```

+ IF [ 130] Read data

    AND    DO: Assign Variable

           recdatef$:=dt$[2]

    AND    DO: Assign Variable

           recdatef:=date(recdatef$)

+ AND [ 158] test today

    AND    DO: Restart Rule

OR        DO: Succeed

```

[158] test today Sp

```

IF        DO: Assign Variable

           today$:=date$(today)

    AND    DO: Assign Variable

           recdatef$:=date$(recdatef)

    AND    DO: Test Expression

           today$=recdatef$

    AND    DO: Assign Variable

           ordnb$[i]:=dt$[1]

    AND    DO: Assign Variable

           i:=i+1

+ AND [ 105] Goto next

+ OR [ 105] Goto next

```


[69] Do action

Sp

IF DO: Assign Variable

sact\$:=left\$(act\$,1)

AND DO: Test Expression

!("U"=sact\$)

+ AND [39] Clear out fields

AND DO: Fail

OR DO: Test Expression

"N"=sact\$

+ AND [105] Goto next

OR DO: Test Expression

"P"=sact\$

AND DO: Test Expression

act\$="Prior"

+ AND [106] Goto prior

OR DO: Test Expression

"F"=sact\$

+ AND [103] Goto first

OR DO: Test Expression

"L"=sact\$

+ AND [104] Goto last

OR DO: Test Expression

"A"=sact\$

+ AND [4] Add record

OR DO: Test Expression

"U"=sact\$

+ AND [167] Update menu

OR DO: Test Expression

"Q"=sact\$

AND DO: Assign Variable

finished:=1

OR DO: Test Expression

"D"=sact\$

AND DO: Test Expression

!recdel

+ AND [162] Turn off errors

+ AND [62] Delete record

OR DO: Test Expression

"R"=sact\$

AND DO: Test Expression

recdel

+ AND [162] Turn off errors

+ AND [133] Recall record

OR DO: Test Expression

act\$="Pack"

+ AND [127] Pack

OR DO: Succeed

[106] Goto prior Sp

+ IF [38] Clear error flag

AND DO: Test Expression

DBprior()

+ AND [27] Check for error

[104] Goto last Sp

+ IF [38] Clear error flag

AND DO: Test Expression

DBlast()

+ AND [27] Check for error

[4] Add record Sp

IF DO: Assign Variable

drinkno:=DBappend()

+ AND [91] Get data

+ AND [180] Write data record

[91] Get data Sp

F IF DO: Help Explain

AND DO: Fail

+ AND [176] update the supporting files

+ OR [52] Convert to numbers

[176] update the supporting files Sp

+ IF [171] update the db when update and delete

[171] update the db when update and delete Sp

+ IF [72] estimate requirements for up and del

+ AND [137] select database

+ AND [103] Goto first

AND DO: Assign Variable

nof1:=DBgetflds(inv1\$[#],inv11\$[#],inv1[#],inv11[#])

+ AND [40] clear out fields for inv1

+ AND [132] read data form inv1 file

+ AND [25] check date with in the week for inv1 for up&del

+ OR [179] Wipe

[72] estimate requirements for up and del Sp

```

IF      DO: Assign Variable
      deli:=date(oldval${2})

AND     DO: Assign Variable
      daynam$:=left$(day$(deli),3)

[ 137] select database                               Sp
      + IF [ 139] select db

[ 139] select db                                     Sp
      + IF [ 38] Clear error flag

      AND     DO: Test Expression
            DBselect(drfh1)

      + AND [ 27] Check for error

[ 40] clear out fields for inv1                       Sp
      IF      DO: Test Expression
            arrclr(dtinv1${#})

      AND     DO: Test Expression
            arrclr(dtinv1[#])

[ 132] read data form inv1 file                       Sp
      + IF [ 117] load all fldsinv1

      + AND [ 151] test for delete mark for inv1

      AND     DO: Assign Variable
            recsubi1:=0

      + AND [ 55] convert to text for inv1

[ 117] load all fldsinv1                               Sp

```

```

IF      DO: Test Expression
        erron()

AND     DO: Test Expression
        DBreadrec(dtinv1[#])

AND     DO: Test Expression
        DBreadrec(dtinv1$[#])

AND     DO: Assign Variable
        recsubi1:=0

[ 151] test for delete mark for inv1      Sp

+ IF   [ 162] Turn off errors

+ AND [ 62] Delete record

    AND     DO: Assign Variable
            recdeli1:=0

+ AND [ 133] Recall record

    OR      DO: Assign Variable
            recdeli1:=1

[ 55] convert to text for inv1      Sp

    IF      DO: Assign Variable
            cnti1:=0

+ AND [ 50] convert loop for inv1

[ 50] convert loop for inv1      Sp

    IF      DO: Test Expression
            inv11$[cnti1]="N"

```

```

AND      DO: Assign Variable

          dtinv1$[cnti1]:=string$(dtinv1[cnti1],inv1[cnti1],inv11[cnti1])

AND      DO: Fail


OR       DO: Test Expression

          inv11$[cnti1]="L"

AND      DO: Assign Variable

          dtinv1$[cnti1]:=query$(dtinv1[cnti1],"T","F")

AND      DO: Assign Variable

          dtinv1[cnti1]:=0

AND      DO: Fail


OR       DO: Test Expression

          inv11$[cnti1]="D"

AND      DO: Assign Variable

          dtinv1$[cnti1]:=date$(dtinv1[cnti1])

AND      DO: Assign Variable

          dtinv1[cnti1]:=0

AND      DO: Fail


OR       DO: Assign Variable

          cnti1:=cnti1+1

AND      DO: Test Expression

          cnti1<nof1

```

AND DO: Restart Rule

OR DO: Succeed

[25] check date with in the week for inv1 for up&del Sp

+ IF [93] get date for inv1

AND DO: Assign Variable

daynam\$:=left\$(day\$(deli),3)

+ AND [77] find the day for up and del

[93] get date for inv1 Sp

+ IF [11] assign the dates

AND DO: Test Expression

ifoundit<>1

AND DO: Restart Rule

OR DO: Succeed

[11] assign the dates Sp

+ IF [132] read data form inv1 file

AND DO: Assign Variable

delinv1\$:=dtinv1\$[0]

AND DO: Assign Variable

delinv1:=int(date(delinv1\$))

AND DO: Assign Variable

delein1\$:=dtinv1\$[1]

```

AND      DO: Assign Variable

        delein1:=int(date(delein1$))

W AND    DO: Display Form


AND      DO: Test Expression

        deli>=delinv1

AND      DO: Test Expression

        deli<=delein1

AND      DO: Assign Variable

        ifoundit:=1


+ OR [ 105] Goto next

AND      DO: Assign Variable

        ifoundit:=0

[ 77] find the day for up and del          Sp

IF      DO: Assign Variable

        cnti:=2

+ AND [ 90] get and check the day from inv1 for up and del

[ 90] get and check the day from inv1 for up and del    Sp

+ IF [ 132] read data form inv1 file

AND      DO: Assign Variable

        daynam1$:=left$(inv1$[cnti],3)

+ AND [ 28] check for up and del

```

```

W OR      DO: Display Form

[ 28] check for up and del      Sp

+ IF  [ 132] read data form inv1 file

      AND      DO: Test Expression

              (daynam1$<>daynam$)

      AND      DO: Assign Variable

              cnti:=cnti+2

      AND      DO: Test Expression

              cnti<=10

      AND      DO: Assign Variable

              daynam1$:=left$(inv1$[cnti],3)

      AND      DO: Restart Rule

W OR      DO: Display Form

+ AND [ 24] check balance for up and del

[ 24] check balance for up and del      Sp

W IF      DO: Display Form

      AND      DO: Test Expression

              dtinv1[cnti+1]>value(dtinv1$[cnti+1])

      AND      DO: Assign Variable

              dtinv1[cnti+1]:=value(dtinv1$[cnti+1])-value(oldval$[4])

      AND      DO: Assign Variable

              dtinv1[cnti]:=value(dtinv1$[cnti])-value(oldval$[cnti])

      AND      DO: Assign Variable

```


dtinv1[0]:=date(dtinv1\$[0])

AND DO: Assign Variable

dtinv1[1]:=date(dtinv1\$[1])

AND DO: Test Expression

DBwriterec(dtinv1[#])

AND DO: Test Expression

DBwriterec(dtinv1\$[#])

AND DO: Test Expression

DBselect(drfh)

W OR DO: Display Form

WPOS: 2,15,10,50

[52] Convert to numbers Sp

+ IF [128] Prepare for convert

+ AND [48] Convert loop back

[128] Prepare for convert Sp

IF DO: Assign Variable

hsh\$="#####"

AND DO: Assign Variable

cnt:=0

+ AND [37] Clear dt[#]

[37] Clear dt[#] Sp

IF DO: Test Expression

arrclr(dt[#])

[48] Convert loop back Sp

IF DO: Test Expression

b\$[cnt]="N"

+ AND [122] Number conversion back

AND DO: Fail

OR DO: Test Expression

b\$[cnt]="L"

+ AND [119] Logical conversion back

AND DO: Fail

OR DO: Test Expression

b\$[cnt]="D"

+ AND [162] Turn off errors

+ AND [38] Clear error flag

+ AND [147] Tate conversion back

AND DO: Fail

OR DO: Assign Variable

cnt:=cnt+1

AND DO: Test Expression

cnt<nof

AND DO: Restart Rule

OR DO: Succeed

[122] Number conversion back Sp

IF DO: Assign Variable

dt[cnt]:=value(dt\$[cnt])

AND DO: Assign Variable

ll:=c[cnt]-d[cnt]-(d[cnt]>0)

AND DO: Test Expression

dt[cnt]<10^ll

OR DO: Assign Variable

form\$:=left\$(hsh\$,ll)+". "+left\$(hsh\$,d[cnt])

AND DO: Assign Variable

prob\$:="Invalid Number Use format "+form\$

+ AND [89] Fix errors

[89] Fix errors Sp

F IF DO: Help Explain

AND DO: Assign Variable

cnt:=cnt-1

[119] Logical conversion back Sp

IF DO: Assign Variable

e\$:=dt\$[cnt]

AND DO: Test Expression

e\$="T"|e\$="1"|e\$="true"|e\$="Y"|e\$="Yes"

AND DO: Assign Variable

dt\$[cnt]:="T"

AND DO: Assign Variable

dt[cnt]:=1

OR DO: Assign Variable

dt\$[cnt]:="F"

AND DO: Assign Variable

dt[cnt]:=0

[147] Tate conversion back Sp

IF DO: Assign Variable

dt[cnt]:=date(dt\$[cnt])

+ AND [27] Check for error

OR DO: Assign Variable

prob\$:="Invalid Date Please Reenter as "+dt\$

+ AND [89] Fix errors

[180] Write data record Sp

IF DO: Test Expression

DBwriterec(dt\$[#])

AND DO: Test Expression

DBwriterec(dt[#])

[167] Update menu Sp

+ IF [91] Get data

+ AND [180] Write data record

[127] Pack Sp

+ IF [38] Clear error flag

AND DO: Test Expression

DBpack()

+ AND [27] Check for error

[135] req Sp

+ IF [103] Goto first

AND DO: Assign Variable

last:=0

AND DO: Assign Variable

lastsos:=0

+ AND [7] arrest

[7] arrest Sp

+ IF [100] getdate

+ AND [22] check and estimate

AND DO: Test Expression

lastsos=0

AND DO: Restart Rule

[100] getdate Sp

```

+ IF [ 130] Read data

      AND      DO: Assign Variable

              deli$:=dt$[2]

      AND      DO: Assign Variable

              deli:=date(deli$)

      AND      DO: Assign Variable

              theol:=0

      AND      DO: Assign Variable

              ind:=1

```

[22] check and estimate Sp

```

+ IF [ 29] check if it is estimated

      OR      DO: Test Expression

              last=1

```

[29] check if it is estimated Sp

```

+ IF [ 153] test if yes

+ AND [ 181] write the new data

+ AND [ 45] continue the calcu

+ OR [ 30] check if this is the last

      AND      DO: Assign Variable

              last:=1

+ AND [ 130] Read data

```

AND DO: Assign Variable

deli\$:=dt\$[2]

AND DO: Test Expression

deli=date(deli\$)

[153] test if yes Sp

IF DO: Test Expression

dt\$[0]="F"

AND DO: Assign Variable

theo1:=theo1+dt[4]

[181] write the new data Sp

IF DO: Assign Variable

dt\$[0]="T"

AND DO: Assign Variable

dt[0]:=1

AND DO: Assign Variable

dt[1]:=value(dt\$[1])

AND DO: Assign Variable

dt[2]:=date(dt\$[2])

AND DO: Assign Variable

dt[3]:=date(dt\$[3])

AND DO: Assign Variable

dt[5]:=value(dt\$[5])

AND DO: Test Expression

```

        DBwriterec(dt$[#])

    AND      DO: Test Expression

        DBwriterec(dt$[#])

[ 45] continue the calcul          Sp

    + IF  [ 178] where to go

    +  AND [ 130] Read data

        AND      DO: Assign Variable

            delic$:=dt$[2]

        AND      DO: Test Expression

            deli=int(date(delic$))

        AND      DO: Restart Rule


    + OR  [ 68] distribute

[ 178] where to go          Sp

    + IF  [ 21] CHECK AGAIN IF IT IS BEEN CHECKED


        OR      DO: Fail

[ 21] CHECK AGAIN IF IT IS BEEN CHECKED          Sp

    + IF  [ 105] Goto next

    +  AND [ 130] Read data

        AND      DO: Assign Variable

            sos:=1

        AND      DO: Assign Variable

            deli$:=dt$[2]

```



```

AND      DO: Test Expression

        deli=date(deli$)

AND      DO: Assign Variable

        sos:=0

AND      DO: Test Expression

        dt$[0]="f"

AND      DO: Assign Variable

        dt$[0]:="T"

AND      DO: Assign Variable

        dt[0]:=1

AND      DO: Assign Variable

        dt[1]:=value(dt$[1])

AND      DO: Assign Variable

        dt[2]:=date(dt$[2])

AND      DO: Assign Variable

        dt[3]:=date(dt$[3])

AND      DO: Assign Variable

        dt[5]:=value(dt$[5])

AND      DO: Test Expression

        DBwriterec(dt[#])

AND      DO: Test Expression

        DBwriterec(dt$[#])

AND      DO: Assign Variable

        theo1:=theo1+dt[4]

```

OR DO: Test Expression

sos=0

+ AND [105] Goto next

OR DO: Fail

[68] distribute Sp

+ IF [75] find date

+ AND [137] select database

+ AND [103] Goto first

AND DO: Assign Variable

nof1:=DBgetflds(inv1\$[#],inv11\$[#],inv1[#],inv11[#])

+ AND [40] clear out fields for inv1

+ AND [132] read data form inv1 file

+ AND [107] heck date with in the week for inv1

+ OR [179] Wipe

[75] find date Sp

IF DO: Assign Variable

daynam\$:=day\$(deli)

[107] heck date with in the week for inv1 Sp

+ IF [93] get date for inv1
 AND DO: Assign Variable
 daynam\$:=left\$(day\$(deli),3)

+ AND [110] ind the day

[110] ind the day Sp

IF DO: Assign Variable
 cnti:=2

+ AND [99] getand check the day from inv1

[99] getand check the day from inv1 Sp

+ IF [132] read data form inv1 file

AND DO: Assign Variable
 daynam1\$:=left\$(inv1\$[cnti],3)

+ AND [20] check

W OR DO: Display Form
 WPOS: 2,15,10,50

AND DO: Fail

[20] check Sp

+ IF [132] read data form inv1 file

AND DO: Test Expression

(daynam1\$<>daynam\$)

AND DO: Assign Variable

cnti:=cnti+2

AND DO: Test Expression

cnti<=10

AND DO: Assign Variable

daynam1\$:=left\$(inv1\$[cnti],3)

AND DO: Restart Rule

+ OR [23] check balance

[23] check balance

Sp

IF DO: Test Expression

dtinv1[cnti]-dtinv1[cnti+1]>=theo1

+ AND [165] update and allocate

+ OR [134] release a kanban order

[165] update and allocate

Sp

IF DO: Assign Variable

dtinv1[cnti+1]:=value(dtinv1\$[cnti+1])+theo1

AND DO: Assign Variable

dtinv1[0]:=date(dtinv1\$[0])

AND DO: Assign Variable
dtinv1[1]:=date(dtinv1\$[1])

AND DO: Test Expression
DBwriterec(dtinv1[#])

AND DO: Test Expression
DBwriterec(dtinv1\$[#])

+ AND [173] update the following's day inv

AND DO: Test Expression
DBselect(drfh)

W OR DO: Display Form

WPOS: 2,15,10,50

Could you please add more inventory records

because I can not schedule the orders

AND DO: Fail

[173] update the following's day inv Sp

+ IF [132] read data form inv1 file

AND DO: Assign Variable
differ:=value(dtinv1\$[cnti])-value(dtinv1\$[cnti+1])

+ AND [160] the next record inv

+ AND [70] do it for all the inv records

AND DO: Restart Rule

OR DO: Succeed

[160] the next record inv Sp

IF DO: Test Expression

cnti<=8

AND DO: Test Expression

differ>=value(dtinvl\$[cnti+3])

AND DO: Assign Variable

dtinv1[cnti+2]:=differ

AND DO: Assign Variable

dtinv1[0]:=date(dtinvl\$[0])

AND DO: Assign Variable

dtinv1[1]:=date(dtinvl\$[1])

AND DO: Test Expression

DBwriterec(dtinvl[#])

AND DO: Test Expression

DBwriterec(dtinvl\$[#])

+ AND [2] ***AVE TO FIND THE DATE AND CHANGECONTI

+ AND [16] cancel the release of kanban orders

OR DO: Test Expression

cnti<=8

+ AND [136] rescheduling

OR DO: Succeed

[2] ***AVE TO FIND THE DATE AND CHANGECONTI Sp

IF DO: Assign Variable

STARTD:=date(dtinvl\$[0])

AND DO: Assign Variable

datenam1\$:=left\$(invl\$[cnti+2],3)

[16] cancel the release of kanban orders Sp

+ IF [111] init the requiremetns

+ AND [26] CHECK DATES FOR REQUIREMENTS

AND DO: Assign Variable

cntr:=2

+ AND [64] delete the orders

+ AND [131] read data for requirements

AND DO: Test Expression

DBselect(drfh1)

+ AND [132] read data form invl file

[111] init the requiremetns Sp

+ IF [140] select requirements

+ AND [103] Goto first

AND DO: Assign Variable

nof2:=DBgetflds(req1\$[#],req11\$[#],req1[#],req11[#])

+ AND [41] clear out fileds for requirements

+ AND [131] read data for requirements

[140] select requirements Sp

```

+ IF [ 38] Clear error flag

      AND      DO: Test Expression

              DBselect(drfh2)

```

```

+ AND [ 27] Check for error

```

```

[ 41] clear out fields for requirements      Sp

```

```

      IF      DO: Test Expression

              arrclr(dtreq$[#])

      AND      DO: Test Expression

              arrclr(dtreq[#])

```

```

[ 131] read data for requirements      Sp

```

```

+ IF [ 116] load all fields for requirements

+ AND [ 152] test for delete mark for requirements

+ AND [ 56] convert to text for requirements

```

```

[ 116] load all fields for requirements      Sp

```

```

      IF      DO: Test Expression

              erron()

      AND      DO: Test Expression

              DBreadrec(dtreq$[#])

      AND      DO: Test Expression

              DBreadrec(dtreq[#])

      AND      DO: Assign Variable

```


recsuc2:=0

[152] test for delete mark for requirements Sp

+ IF [162] Turn off errors

+ AND [62] Delete record

AND DO: Assign Variable

recdel2:=0

+ AND [133] Recall record

OR DO: Assign Variable

recdel2:=1

[56] convert to text for requirements Sp

IF DO: Assign Variable

cntr:=0

+ AND [51] convert loop for requirements

[51] convert loop for requirements Sp

IF DO: Test Expression

req11[cntr]="N"

AND DO: Assign Variable

dtreq[cntr]:=string\$(dtreq[cntr],req1[cntr],req11[cntr])

AND DO: Fail

```

OR      DO: Test Expression

        req11$[cntr]="L"

AND     DO: Assign Variable

        dtreq$[cntr]:=query$(dtreq[cntr],"T","F")

AND     DO: Assign Variable

        dtreq[cntr]:=0

AND     DO: Fail


OR      DO: Test Expression

        req11$[cntr]="D"

AND     DO: Assign Variable

        dtreq$[cntr]:=date$(dtreq[cntr])

AND     DO: Assign Variable

        dtreq[cntr]:=0

AND     DO: Fail


OR      DO: Assign Variable

        cntr:=cntr+1

AND     DO: Test Expression

        cntr<nof2

AND     DO: Restart Rule


OR      DO: Succeed

```

[26] CHECK DATES FOR REQUIREMENTS

Sp

+ IF [84] find the record for the requirements

AND DO: Test Expression

rfoundit<>1

AND DO: Restart Rule

OR DO: Succeed

[84] find the record for the requirements

Sp

+ IF [131] read data for requirements

AND DO: Assign Variable

DELIREQ:=int(date(dtreq\$[0]))

AND DO: Assign Variable

DELEREQ:=int(date(dtreq\$[1]))

AND DO: Test Expression

deli-7<=DELEREQ

AND DO: Test Expression

deli-7>=DELIREQ

AND DO: Assign Variable

rfoundit:=1

+ OR [105] Goto next

AND DO: Assign Variable

rfoundit:=0

[64] delete the orders Sp

```
IF      DO: Assign Variable
      DAYNMR$:=left$(req1$[cntr],3)

AND     DO: Test Expression
      datenam1$<>DAYNMR$

AND     DO: Assign Variable
      cntr:=cntr+1

AND     DO: Restart Rule
```

+ OR [17] cancel the scheduled orders

[17] cancel the scheduled orders Sp

```
IF      DO: Assign Variable
      dtreq[0]:=date(dtreq$[0])

AND     DO: Assign Variable
      dtreq[1]:=date(dtreq$[1])

AND     DO: Assign Variable
      dtreq[cntr]:=0

AND     DO: Test Expression
      DBwriterec(dtreq[#])

AND     DO: Test Expression
      DBwriterec(dtreq$[#])
```

+ AND [131] read data for requirements

AND DO: Test Expression

DBselect(drfh1)

[136] rescheduling

Sp

IF DO: Assign Variable

demand:=value(dtinv1\$[cnti+3])-differ

AND DO: Assign Variable

quantity:=demand

+ AND [156] test the remainder to update the inv for resc

+ AND [182] write the new data in inv

+ AND [2] ***AVE TO FIND THE DATE AND CHANGECONTI

+ AND [169] update requirements in rescheduling

AND DO: Test Expression

DBselect(drfh1)

+ AND [132] read data form inv1 file

[156] test the remainder to update the inv for resc

Sp

IF DO: Test Expression

quantity/10>=1

+ AND [109] if it is indeed

OR DO: Assign Variable

dtinv1[cnti+2]:=10+differ

AND DO: Assign Variable

nbrord:=1

[109] if it is indeed Sp

IF DO: Test Expression

mod(quantity,10)=0

AND DO: Assign Variable

dtinv1[cti+2]:=value(dtinv1\$[cti+2])+quantity

AND DO: Assign Variable

nbrord:=quantity/10

OR DO: Assign Variable

dtinv1[cti+2]:=value(dtinv1\$[cti+2])+quantity+10-
mod(quantity,10)

AND DO: Assign Variable

nbrord:=int(quantity/10)+1

[182] write the new data in inv Sp

IF DO: Assign Variable

dtinv1[0]:=date(dtinv1\$[0])

AND DO: Assign Variable

dtinv1[1]:=date(dtinv1\$[1])

/ AND DO: Test Expression

DBwriterec(dtinv1[#])

AND DO: Test Expression

DBwriterec(dtinvl\$[#])

[169] update requirements in rescheduling Sp

IF DO: Test Expression

DBselect(drfh2)

+ AND [111] init the requiremetns

+ AND [26] CHECK DATES FOR REQUIREMENTS

AND DO: Assign Variable

cntr:=2

+ AND [59] day for requirements rescheduling

[59] day for requirements rescheduling Sp

+ IF [10] assign cntr value

+ AND [126] overwrite the requirements

[10] assign cntr value Sp

IF DO: Test Expression

cnti+2=2

AND DO: Assign Variable

cntr:=2

OR DO: Test Expression

cnti+2=4

AND DO: Assign Variable

cntr:=3

OR DO: Test Expression

cnti+2=6

AND DO: Assign Variable

cntr:=4

OR DO: Test Expression

cnti+2=8

AND DO: Assign Variable

cntr:=5

OR DO: Test Expression

cnti+2=10

AND DO: Assign Variable

cntr:=6

[126] overwrite the requirements

Sp

IF DO: Assign Variable

dtreq[cntr]:=nbrord

AND DO: Assign Variable

dtreq[0]:=date(dtreq\$[0])

AND DO: Assign Variable

dtreq[1]:=date(dtreq\$[1])


```

AND      DO: Test Expression

          DBwriterec(dtreq[#])

AND      DO: Test Expression

          DBwriterec(dtreq$[#])

AND      DO: Test Expression

          DBselect(drfl1)

```

[70] do it for all the inv records Sp

```

IF      DO: Assign Variable

          cnti:=cnti+2

AND     DO: Test Expression

          cnti<=10

OR      DO: Assign Variable

          differ:=value(dtinvl$[cnti-2])-value(dtinvl$[cnti-1])

+ AND [ 105] Goto next

+ AND [ 132] read data form inv1 file

AND     DO: Assign Variable

          deli:=deli+7

AND     DO: Assign Variable

          cnti:=0

+ AND [ 160] the next record inv

AND     DO: Assign Variable

          cnti:=cnti+2

```

Sp

+ IF [33] check the lead time

AND DO: Assign Variable

```
quantity:=theo1-(value(dtinv1$[cnti])-value(dtinv1$[cnti+1]))
```

AND DO: Assign Variable

$$\text{dtinv1}[\text{cnti}+1] := \text{value}(\text{dtinv1}[\text{cnti}+1]) + \text{theo1}$$

- + AND [155] test the remainder to update the inv

AND DO: Assign Variable

```
dtinv1[0]:=date(dtinv1$(0))
```

AND DO: Assign Variable

```
dtinv1[1]:=date(dtinv1$[1])
```

AND **DO: Test Expression**

DBwriterec(dtinvl[#])

AND DO: Test Expression

DBwriterec(dtinv1\$[#])

- + AND [175] update the requirements

+ AND [173] update the following's day inv

AND DO: Test Expression

DBselect(drfh)

W OR DO: Display Form

WPOS: 2,15,10,50

You have to delay the order because there is
not enough time for production

COL : SURR Yellow on Red

COL : 0,0 Yellow on Red

+ AND [19] change the log at the assembly file

AND DO: Quit

[33] check the lead time Sp

IF DO: Assign Variable

clead:=now()

AND DO: Test Expression

clead<=deli+7

OR [161] their is no time for the fabn

AND DO: Fail

[161] their is no time for the fabn Sp

[155] test the remainder to update the inv Sp

IF DO: Test Expression

quantity/10>=1

+ AND [108] if it is

OR DO: Assign Variable

dtinv1[cti]:=value(dtinv1\${cti})+10

AND DO: Assign Variable

nbrord:=1

[108] if it is Sp

IF DO: Test Expression

mod(quantity,10)=0

AND DO: Assign Variable

dtinv1[cti]:=value(dtinv1\${cti})+quantity

AND DO: Assign Variable

nbrord:=quantity/10

OR DO: Assign Variable

dtinv1[cti]:=value(dtinv1\${cti})+quantity+10-mod(quantity,10)

AND DO: Assign Variable

nbrord:=int(quantity/10)+1

[175] update the requirements Sp

+ IF [111] init the requiremetns

+ AND [26] CHECK DATES FOR REQUIREMENTS

AND DO: Assign Variable

cntr:=2

+ AND [96] GET THE DAY FOR REQUIREMENTS

+ AND [131] read data for requirements

AND DO: Test Expression

DBselect(drfh1)

[96] GET THE DAY FOR REQUIREMENTS Sp

IF DO: Assign Variable

DAYNMRS:=left\$(req1\$[cntr],3)

AND DO: Test Expression

daynam1\$<>DAYNMRS

AND DO: Assign Variable

cntr:=cntr+1

AND DO: Test Expression

cntr<7

AND DO: Restart Rule

+ OR [172] UPDATE THE DBFILE WITH THE NEW
REQUIREMENTS

[172] UPDATE THE DBFILE WITH THE NEW REQUIREMENTS Sp

IF DO: Assign Variable

dtreq[cntr]:=value(dtreq\$[cntr])+nbrord

AND DO: Assign Variable

dtreq[0]:=date(dtreq\$[0])

AND DO: Assign Variable

dtreq[1]:=date(dtreq\$[1])

AND DO: Test Expression
DBwriterec(dtreq[#])

AND DO: Test Expression
DBwriterec(dtreq\$[#])

[19] change the log at the assembly file Sp

IF DO: Test Expression
DBselect(drfh)

AND DO: Assign Variable
dt[0]:=0

AND DO: Assign Variable
dt[1]:=value(dt\$[1])

AND DO: Assign Variable
dt[2]:=date(dt\$[2])

AND DO: Assign Variable
dt[3]:=date(dt\$[3])

AND DO: Assign Variable
dt[5]:=value(dt\$[5])

AND DO: Test Expression
DBwriterec(dt[#])

AND DO: Test Expression
DBwriterec(dt\$[#])

[30] check if this is the last Sp

+ IF [105] Goto next

OR DO: Assign Variable

lastsos:=1

[43] CLOSE THE ORDERS IN DSS Sp

+ IF [112] Initialise

W AND DO: Display Form

WPOS: 1,1,23,78

could you pls type in the number of the orders that are
finished?

+ AND [103] Goto first

AND DO: Assign Variable

i:=0

+ AND [81] find the jobs1

[81] find the jobs1 Sp

+ IF [80] find the jobs

AND DO: Restart Rule

[80] find the jobs Sp

```

+ IF [ 130] Read data

      AND DO: Test Expression

            order$[i]=dt$[1]

      AND DO: Assign Variable

            i:=i+1

+ AND [ 42] close the ord

+ AND [ 105] Goto next

+ OR [ 105] Goto next

```

[42] close the ord Sp

```

IF DO: Assign Variable

      dt[5]:=1

AND DO: Assign Variable

      dt[2]:=date(dt$[2])

AND DO: Assign Variable

      dt[3]:=int(now())

AND DO: Assign Variable

      dt[0]:=value(dt$[0])

AND DO: Assign Variable

      dt[4]:=value(dt$[4])

AND DO: Assign Variable

      dt[1]:=value(dt$[1])

AND DO: Test Expression

```


DBwriterec(dt[#])

AND DO: Test Expression

DBwriterec(dt\$[#])

[125] OPEN REQ AND GET DATA Sp

+ IF [142] Set fixed values

+ AND [44] Closedown

AND DO: Assign Variable

drfh2:=DBopen("a:\req")

+ AND [111] init the requiremetns

+ AND [103] Goto first

+ AND [88] find today's requirements

+ AND [44] Closedown

[88] find today's requirements Sp

IF DO: Assign Variable

today:=now()

+ AND [85] find the record in the rq

W AND DO: Display Form

WPOS: 1,1,23,78

The number of orders that should be released today is:

* [nbrreq\$] *

You have to receive today [nbre] of kanban containers

W OR DO: Display Form

WPOS: 2,15,10,50

There are no orders to be released.

[85] find the record in the rq Sp

+ IF [131] read data for requirements

+ AND [149] test date for rq

[149] test date for rq Sp

+ IF [131] read data for requirements

AND DO: Assign Variable

daterecl\$:=dtreq\$[1]

AND DO: Assign Variable

datereqf\$:=dtreq\$[0]

AND DO: Assign Variable

daterecl:=date(daterecl\$)

AND DO: Assign Variable

daterecf:=date(datereqf\$)

+ AND [159] test today req

AND DO: Test Expression

logts=1

AND DO: Restart Rule

OR DO: Succeed

[159] test today req Sp

IF DO: Test Expression

int(today)<=daterecl

AND DO: Test Expression

int(today)>=daterecf

+ AND [76] find the day for today

AND DO: Assign Variable

logts:=0

+ OR [105] Goto next

AND DO: Assign Variable

logts:=1

[76] find the day for today Sp

+ IF [131] read data for requirements

AND DO: Assign Variable

cntr:=2+int(today)-daterecf

AND DO: Assign Variable

nbrreq\$:=dtreq\$[cntr]

+ AND [106] Goto prior

+ AND [131] read data for requirements

AND DO: Assign Variable

nbreqq:=value(dtreq\$[cntr])

[164] unexpected inv replenishment Sp

+ IF [113] initil the inv

AND DO: Assign Variable

drfh2:=DBopen("a:\req")

+ AND [95] get the date and quantity

+ AND [174] UPDATE THE INV WITH THE UNEXPECTED

+ AND [44] Closedown

[113] initil the inv Sp

+ IF [139] select db

AND DO: Assign Variable

nof1:=DBgetflds(inv1\$[#],inv11\$[#],inv1[#],inv11[#])

+ AND [103] Goto first

+ AND [40] clear out fields for inv1

+ AND [132] read data form inv1 file

+ OR [179] Wipe

[95] get the date and quantity Sp

W IF DO: Display Form

WPOS: 1,1,23,78

COULD YOU TYPE IN THE DATE YOU RECEIVED
THE ORDER(S) OR YOU WILL RECEIVE, AND THE QUANTITY THAT
YOU EXPECT FROM FABN

DATE : <NEWINVD\$ >

QUANTITY : <NEWINVQ >

[174] UPDATE THE INV WITH THE UNEXPECTED Sp

IF DO: Assign Variable

NEWINVD:=date(NEWINVD\$)

AND DO: Assign Variable

NINVDY\$:=left\$(day\$(NEWINVD),3)

+ AND [103] Goto first

+ AND [157] TEST TO FIND THE WEKK

[157] TEST TO FIND THE WEKK Sp

+ IF [148] TEST AND FIND WEEK

AND DO: Assign Variable

not_again:=1

AND DO: Restart Rule

OR DO: Succeed

[148] TEST AND FIND WEEK Sp

+ IF [132] read data form inv1 file

```

AND      DO: Assign Variable

          STARTDD$:=dtinv1$[0]

AND      DO: Assign Variable

          STARTDD:=date(STARTDD$)

AND      DO: Assign Variable

          ENDD$:=dtinv1$[1]

AND      DO: Assign Variable

          ENDD:=date(ENDD$)

AND      DO: Test Expression

          NEWINVD>=STARTD

AND      DO: Test Expression

          NEWINVD<=ENDD

AND      DO: Assign Variable

          not_again:=1

+ AND [ 144] START TO UPDBINV

+ OR  [ 105] Goto next

W OR      DO: Display Form

          WPOS: 2,15,10,50

          I DID NOT FIND THE DATE IN THE DATABASE

          COL : SURR      White on Blue

          COL : 0,0      White on Blue

```

AND DO: Fail

[144] START TO UPDBINV Sp

IF DO: Assign Variable

not_again:=0

AND DO: Assign Variable

deli:=NEWINVD

AND DO: Assign Variable

cnti:=2

+ AND [79] FIND THE DAYNAME

[79] FIND THE DAYNAME Sp

+ IF [14] assign the right value to cnti

+ AND [13] assign the first value for differ

+ AND [1] \$\$ADD THE EXTRA INVENTORY

[14] assign the right value to cnti Sp

IF DO: Assign Variable

tst:=NEWINVD-STARTDD

AND DO: Test Expression

tst=0

AND DO: Assign Variable

cnti:=2

OR DO: Assign Variable

cnti:=2*tst+2

[13] assign the first value for differ Sp

IF DO: Test Expression

cnti=2

+ AND [106] Goto prior

+ AND [132] read data form inv1 file

AND DO: Assign Variable

differ:=value(dtinvl\$[10])-value(dtinvl\$[11])

+ AND [105] Goto next

+ AND [132] read data form inv1 file

+ OR [132] read data form inv1 file

AND DO: Assign Variable

differ:=value(dtinvl\$[cnti-2])-value(dtinvl\$[cnti-1])

[1] \$\$ADD THE EXTRA INVENTORY Sp

IF DO: Test Expression

deli<int(now()+7

+ AND [5] ADD THE NEW QUANTITY

AND DO: Restart Rule

OR DO: Test Expression

deli>=now()+7

+ AND [34] check the release for cancellation

AND DO: Restart Rule

[5] ADD THE NEW QUANTITY Sp

IF DO: Test Expression

cnti<=10

AND DO: Assign Variable

dtinv1[0]:=date(dtinv1\$[0])

AND DO: Assign Variable

dtinv1[1]:=date(dtinv1\$[1])

AND DO: Assign Variable

dtinv1[cnti]:=value(dtinv1\$[cnti])+NEWINVQ

AND DO: Test Expression

DBwriterec(dtinv1\$[#])

AND DO: Test Expression

DBwriterec(dtinv1[#])

+ AND [132] read data form inv1 file

AND DO: Assign Variable

differ:=value(dtinv1\$[cnti])-value(dtinv1\$[cnt+1])

AND DO: Assign Variable

cnti:=cnti+2

+ OR [105] Goto next

+ AND [132] read data form inv1 file

AND DO: Assign Variable

deli:=date(dtinv1\$[0])

AND DO: Assign Variable

cnti:=2

[34] check the release for cancellation Sp

+ IF [132] read data form inv1 file

AND DO: Test Expression

value(dtinv1\$[cnti+1])<=differ

AND DO: Assign Variable

dtinv1[0]:=date(dtinv1\$[0])

AND DO: Assign Variable

dtinv1[1]:=date(dtinv1\$[1])

AND DO: Assign Variable

dtinv1[cnti]:=differ

AND DO: Test Expression

DBwriterec(dtinv1\$[#])

AND DO: Test Expression

DBwriterec(dtinv1\$[#])

AND DO: Assign Variable

daynam1\$:=left\$(day\$(deli),3)

+ AND [168] update req for unexpected replenishment

+ AND [132] read data form inv1 file

AND DO: Assign Variable

differ:=dtinv1[cnti]-dtinv1[cnti+1]

+ AND [9] assign and check cnti

OR DO: Assign Variable

quantity:=value(dtinv1\$[cnti+1])-differ

AND DO: Assign Variable

dtinv1[0]:=date(dtinv1\$[0])

AND DO: Assign Variable

dtinv1[1]:=date(dtinv1\$[1])

+ AND [155] test the remainder to update the inv

AND DO: Test Expression

DBwriterec(dtinv1\$[#])

AND DO: Test Expression

DBwriterec(dtinv1[#])

+ AND [169] update requirements in rescheduling

+ AND [9] assign and check cnti

[168] update req for unexpected replenishment Sp

+ IF [111] init the requiremetns

+ AND [26] CHECK DATES FOR REQUIREMENTS

AND DO: Assign Variable

cntr:=2

+ AND [60] day for requirements unexpected inventory

[60] day for requirements unexpected inventory Sp

IF DO: Assign Variable

 cntr:=deli-5-date(dtreq\$[0])

+ AND [17] cancel the scheduled orders

[9] assign and check cnti Sp

IF DO: Assign Variable

 cnti:=cnti+2

AND DO: Test Expression

 cnti<=10

AND DO: Assign Variable

 deli:=deli+1

+ OR [105] Goto next

AND DO: Assign Variable

 cnti:=2

+ AND [132] read data form inv1 file

AND DO: Assign Variable

 deli:=date(dtinv1\$[0])

[170] update the assembly orders Sp

W IF DO: Menu Question upmenu

WPOS: 1,1,23,78

Please define what kind of information you want to
change concerning the assembly order

- 1) {Starting Date }
- 2) {Quantity }
- 3) {Both the above }
- 4) {Delete an order }

AND DO: Test Expression

upmenu=1

+ AND [146] starting date deleted

OR DO: Test Expression

upmenu=2

+ AND [65] delete the quantity

OR DO: Test Expression

upmenu=3

+ AND [15] both deleted

OR DO: Test Expression

upmenu=4

+ AND [177] update/delete ass order

[146] starting date deleted Sp

+ IF [177] update/delete ass order

W AND DO: Display Form

WPOS: 2,15,10,50

I have deleted the order.

Could you please run the Add module to update
the system.

(press enter to continue)

COL : SURR White on Blue

COL : 0,0 Lt_Blue on Cyan

[177] update/delete ass order Sp

+ IF [112] Initialise

+ AND [103] Goto first

W AND DO: Display Form

WPOS: 2,15,10,50

Could you please type in the order number:

order number:<or_nu\$ >

W AND DO: Display Form

+ AND [82] find the order in the database
+ AND [44] Closedown

[82] find the order in the database Sp

+ IF [130] Read data

W AND DO: Display Form

AND DO: Test Expression

ORDER\$<or_nu\$

+ AND [105] Goto next

AND DO: Restart Rule

W OR DO: Display Form

WPOS: 2,15,10,50

+ AND [185] you found the order to delete

[185] you found the order to delete Sp

IF DO: Assign Variable

cancquan:=value(dt\$[4])

AND DO: Assign Variable

cancdate\$:=dt\$[2]

AND DO: Assign Variable

cancdate:=date(cancdate\$)

+ AND [63] delete the order from the assembly orders file

W AND DO: Display Form

WPOS: 2,15,10,50

+ AND [114] inventory update on the cancellation

[63] delete the order from the assembly orders file Sp

IF DO: Assign Variable

recnum:=DBrecno()

AND DO: Test Expression

DBdelete(recnum)

AND DO: Test Expression

DBpack()

[114] inventory update on the cancellation Sp

+ IF [113] initil the inv

+ AND [103] Goto first

+ AND [132] read data form inv1 file

+ AND [74] find data in inventory

[74] find data in inventory Sp

W IF DO: Display Form

+ AND [87] find the week starting ending dates

AND DO: Assign Variable

NEWINVD:=candate

+ AND [14] assign the right value to cnti

+ AND [18] change the allocated inv and continue

[87] find the week starting ending dates Sp

W IF DO: Display Form

WPOS: 2,15,10,50

AND DO: Assign Variable

STARTDD\$:=dtinv1\$[0]

AND DO: Assign Variable

STARTDD:=date(STARTDD\$)

AND DO: Assign Variable

ENDD\$:=dtinv1\$[1]

AND DO: Assign Variable

ENDD:=date(ENDD\$)

+ AND [86] find the week

AND DO: Test Expression

logtest=0

AND DO: Restart Rule

OR DO: Succeed

[86] find the week Sp

IF DO: Test Expression

```

STARTDD<=candate

AND    DO: Test Expression

ENDDD>=candate

AND    DO: Assign Variable

logtest:=1

W AND    DO: Display Form

WPOS: 2,15,10,50

```

```

+ OR [ 105] Goto next

+ AND [ 132] read data form inv1 file

AND    DO: Assign Variable

logtest:=0

```

[18] change the allocated inv and continue Sp

```

+ IF [ 132] read data form inv1 file

AND    DO: Assign Variable

dtinv1[cti+1]:=value(dtinv1$[cti+1])-cancquan

AND    DO: Assign Variable

dtinv1[0]:=date(dtinv1$[0])

AND    DO: Assign Variable

dtinv1[1]:=date(dtinv1$[1])

AND    DO: Test Expression

DBwriterec(dtinv1[#])

```

```

AND      DO: Test Expression

          DBwriterec(dtinvl$[#])

+ AND [ 132] read data form inv1 file

AND      DO: Assign Variable

          deli:=cancdate

AND      DO: Assign Variable

          NEWINVQ:=cancquan

+ AND [ 98] GET THE PREVIOUS DIFFER

W AND    DO: Display Form

          WPOS: 2,15,10,50

```

```

+ AND [ 101] give cnti the value

+ AND [ -6] ADD1 THE NEW QUANTITY

```

```

[ 98] GET THE PREVIOUS DIFFER                               Sp

IF      DO: Test Expression

          cnti>2

AND      DO: Assign Variable

          differ:=value(dtinvl$[cnti-2])-value(dtinvl$[cnti-1])

W AND    DO: Display Form

/

+ OR [ 106] Goto prior

+ AND [ 132] read data form inv1 file

AND      DO: Assign Variable

```

differ:=value(dtinvl\$[10])-value(dtinvl\$[11])

+ AND [105] Goto next

+ AND [132] read data form inv1 file

AND DO: Assign Variable

cnti:=2

[101] give cnti the value Sp

IF DO: Test Expression

deli<int(now())+7

W AND DO: Display Form

AND DO: Assign Variable

cnti:=cnti+2

OR DO: Succeed

[6] ADD1 THE NEW QUANTITY Sp

IF DO: Test Expression

deli<int(now())+7

+ AND [5] ADD THE NEW QUANTITY

AND DO: Restart Rule

W OR DO: Display Form

+ AND [34] check the release for cancellation

AND DO: Restart Rule

[65] delete the quantity Sp

+ IF [177] update/delete ass order

W AND DO: Display Form

WPOS: 2,15,10,50

I have deleted the order.

Could you please run the Add module to update
the system.

(press enter to continue)

[15] both deleted Sp

+ IF [177] update/delete ass order

W AND DO: Display Form

WPOS: 2,15,10,50

I have deleted the order.

Could you please run the Add module to update
the system.

(press enter to continue)

COL : SURR Lt_Blue on Cyan

COL : 0,0 Lt_Blue on Cyan

